

Mobile Phone Radiation Bio-Effect Studies
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Biological studies on radiation similar to that emitted by cell phones

Aalto S, Haarala C, Bruck A, Sipila H, Hamalainen H, Rinne JO. Mobile phone affects cerebral blood flow in humans. J Cereb Blood Flow Metab. 26(7):885-890, 2006.

Mobile phones create a radio-frequency electromagnetic field (EMF) around them when in use, the effects of which on brain physiology in humans are not well known. We studied the effects of a commercial mobile phone on regional cerebral blood flow (rCBF) in healthy humans using positron emission tomography (PET) imaging. Positron emission tomography data was acquired using a double-blind, counterbalanced study design with 12 male subjects performing a computer-controlled verbal working memory task (letter 1-back). Explorative and objective voxel-based statistical analysis revealed that a mobile phone in operation induces a local decrease in rCBF beneath the antenna in the inferior temporal cortex and an increase more distantly in the prefrontal cortex. Our results provide the first evidence, suggesting that the EMF emitted by a commercial mobile phone affects rCBF in humans. These results are consistent with the postulation that EMF induces changes in neuronal activity.

Abdel-Rassoul G, El-Fateh OA, Salem MA, Michael A, Farahat F, El-Batanouny M, Salem E. Neurobehavioral effects among inhabitants around mobile phone base stations. Neurotoxicology. 2006 Aug 1; [Epub ahead of print]

BACKGROUND: There is a general concern on the possible hazardous health effects of exposure to radiofrequency electromagnetic radiations (RFR) emitted from mobile phone base station antennas on the human nervous system. **AIM:** To identify the possible neurobehavioral deficits among inhabitants living nearby mobile phone base stations. **METHODS:** A cross-sectional study was conducted on (85) inhabitants living nearby the first mobile phone station antenna in Menoufiya governorate, Egypt, 37 are living in a building under the station antenna while 48 opposite the station. A control group (80) participants were matched with the exposed for age, sex, occupation and educational level. All participants completed a structured questionnaire containing: personal, educational and medical histories; general and neurological examinations; neurobehavioral test battery (NBTB) [involving tests for visuomotor speed, problem solving, attention and memory]; in addition to Eysenck personality questionnaire (EPQ). **RESULTS:** The prevalence of neuropsychiatric complaints as headache (23.5%), memory changes (28.2%), dizziness (18.8%), tremors (9.4%), depressive symptoms (21.7%), and sleep disturbance (23.5%) were significantly higher among exposed inhabitants than controls: (10%), (5%), (5%), (0%), (8.8%) and (10%), respectively ($P < 0.05$). The NBTB indicated that the exposed inhabitants exhibited a significantly lower performance than controls in one of the tests of attention and short-term auditory memory [Paced Auditory Serial Addition Test (PASAT)]. Also, the inhabitants opposite the station exhibited a lower performance in the problem solving test (block design) than those under the station. All inhabitants exhibited a better performance in the two tests of visuomotor speed (Digit symbol and Trailmaking B) and one test of attention (Trailmaking A) than controls. The last available measures of RFR emitted from the first mobile phone base station antennas in Menoufiya governorate were less than the allowable standard level. **CONCLUSIONS AND RECOMMENDATIONS:** Inhabitants living nearby mobile phone base stations are at risk for developing neuropsychiatric problems and some changes in the performance of neurobehavioral functions either by facilitation or inhibition. So, revision of standard guidelines for public exposure to RFR from mobile phone base station antennas and using of NBTB for regular assessment and early detection of biological effects among inhabitants around the stations are recommended.

Acar GO, Yener HM, Savrun FK, Kalkan T, Bayrak I, Enver O. Thermal effects of mobile phones on facial nerves and surrounding soft tissue. Laryngoscope. 2009 Jan 21. [Epub ahead of print]

OBJECTIVE: To investigate the possible thermal effects of microwaves from mobile phones on facial nerves (FN) and surrounding soft tissue. **STUDY DESIGN::** A prospective study. **METHODS:** We studied FN conduction rate and compound muscle action potentials (CMAP) on 12 rabbits before exposure to radiofrequency radiation (RFR) emitted from a mobile phone. Also, the temperature change in the soft tissues around the FN was investigated by a four channel Luxtron fiber optic system. A mobile phone with 1900 MHz frequency was placed over the ipsilateral ear of the rabbit for

25 minutes, and FN and surrounding tissues were exposed to a 1.5 watts pulse modulated (217 packets/s) electromagnetic field. During exposure to RFR, immediately after turning off the mobile phone, and 25 minutes after the exposure temperature change in the surrounding tissue of the FN was recorded and compared to preexposure values. Additionally, another recording regarding the FN functions was done and the data were compared to preexposure values. RESULTS: The average temperature of the surrounding soft tissues was 0.39 K higher than the preexposure values during the exposure and immediately after turning off the mobile phone, and decreased to normal levels 25 minutes after the exposure, which was statistically significant. The amplitudes of FN CMAP after radiofrequency radiation exposure were significantly smaller than the preexposure amplitudes and the amplitudes were normal in the 25 minute measurement. CONCLUSION: The RFR emitted from a mobile phone can cause temporary FN dysfunction that can be due to temporary temperature increase in the soft tissue around the FN.

Adey WR, Byus CV, Cain CD, Higgins RJ, Jones RA, Kean CJ, Kuster N, MacMurray A, Stagg RB, Zimmerman G, Phillips JL, Haggren W, Spontaneous and nitrosourea-induced primary tumors of the central nervous system in Fischer 344 rats chronically exposed to 836 MHz modulated microwaves. *Radiat Res* 152(3):293-302, 1999.

We have tested an 836.55 MHz field with North American Digital Cellular (NADC) modulation in a 2-year animal bioassay that included fetal exposure. In offspring of pregnant Fischer 344 rats, we tested both spontaneous tumorigenicity and the incidence of induced central nervous system (CNS) tumors after a single dose of the carcinogen ethylnitrosourea (ENU) in utero, followed by intermittent digital-phone field exposure for 24 months. Far-field exposures began on gestational day 19 and continued until weaning at age 21 days. Near-field exposures began at 35 days and continued for the next 22 months, 4 consecutive days weekly, 2 h/day. SAR levels simulated localized peak brain exposures of a cell phone user. Of the 236 original rats, 182 (77%) survived to the termination of the whole experiment and were sacrificed at age 709-712 days. The 54 rats (23%) that died during the study ("preterm rats") formed a separate group for some statistical analyses. There was no evidence of tumorigenic effects in the CNS from exposure to the TDMA field. However, some evidence of tumor-inhibiting effects of TDMA exposure was apparent. Overall, the TDMA field-exposed animals exhibited trends toward a reduced incidence of spontaneous CNS tumors ($P < 0.16$, two-tailed) and ENU-induced CNS tumors ($P < 0.16$, two-tailed). In preterm rats, where primary neural tumors were determined to be the cause of death, fields decreased the incidence of ENU-induced tumors ($P < 0.03$, two-tailed). We discuss a possible approach to evaluating with greater certainty the possible inhibitory effects of TDMA-field exposure on tumorigenesis in the CNS.

Adey WR, Byus CV, Cain CD, Higgins RJ, Jones RA, Kean CJ, Kuster N, MacMurray A, Stagg RB, Zimmerman G, Spontaneous and nitrosourea-induced primary tumors of the central nervous system in Fischer 344 rats exposed to frequency-modulated microwave fields. *Cancer Res* 60(7):1857-1863, 2000.

In a 2-year bioassay, we exposed Fischer 344 rats to a frequency-modulated (FM) signal (836.55 MHz \pm 12.5 KHz deviation) simulating radiofrequency exposures in the head of users of hand-held mobile phones. We tested for effects on spontaneous tumorigenicity of central nervous system (CNS) tumors in the offspring of pregnant rats and also for modified incidence of primary CNS tumors in rats treated with a single dose of the neurocarcinogen ethylnitrosourea (ENU) in utero. ENU dosage (4 mg/kg) was selected to give an expected brain tumor incidence of 10-15% over the mean life span of 26 months. Pregnant dams ($n = 102$) were randomly assigned to six groups. Their offspring were treated as cohorts in each of the six groups ($n = 90$ per group; total, $n = 540$): Sham ENU/Sham Field, Sham ENU/Field Exposed, ENU/Sham Field, ENU/Field Exposed, ENU/Cage Control, and Sham ENU/Cage Control. Intermittent field exposures began on gestation day 19 and continued until weaning at 21 days, resuming thereafter at 31 days and continuing until experiment termination at 731-734 days. Energy absorption rates (SARs) in the rats' brains were similar to localized peak brain exposures of a phone user (female, 236 g, 1.0 W/kg; male, 450 g, 1.2 W/kg). Of the original 540 rats, 168 died before the termination of the experiment. In these rats, ENU significantly reduced survival from a mean of 708 days in three groups without ENU treatment to 645 days in three groups treated with ENU ($P < 0.0005$). There were no effects on survival attributable to FM field exposure in either ENU-treated or in sham-treated groups. Spontaneous CNS tumor incidence in control groups was 1.1-4.4% but sharply higher in rats receiving ENU (14.4-22.2%; $P < 0.0001$). No FM field-mediated changes were observed in number, incidence, or histological type of either spontaneous or ENU-induced brain tumors, nor were gender differences detected in tumor numbers. These negative findings with FM fields contrast

with our study using standard digital phone fields pulsed on and off at 50/se, where a trend was noted toward reduced incidence of both spontaneous and ENU-induced CNS tumors (W. R. Adey et al., Radiat. Res., 152: 293-302, 1999). Although consistent but not attaining significance in the experiment overall (spontaneous CNS tumors, $P < 0.08$ one-tailed; $P < 0.16$ two-tailed; ENU-induced CNS tumors, $P < 0.08$ one-tailed, $P < 0.16$ two-tailed), the trend was significant ($P < 0.015$ one-tailed, $P < 0.03$, two-tailed) in rats that received ENU and died prior to experiment termination, with a primary brain tumor as the cause of death. We discuss differences in the signaling structure of digital and FM fields. Certain bioeffects induced by either amplitude-modulated or pulsed radiofrequency fields at athermal levels have not been seen with fields of similar average power but unvarying in intensity (continuous wave or frequency-modulated fields).

Agarwal A, Deepinder F, Sharma RK, Ranga G, Li J. Effect of cell phone usage on semen analysis in men attending infertility clinic: an observational study. Fertil Steril. 2007 May 3; [Epub ahead of print]

OBJECTIVE: To investigate the effect of cell phone use on various markers of semen quality. DESIGN: Observational study. SETTING: Infertility clinic. PATIENT(S): Three hundred sixty-one men undergoing infertility evaluation were divided into four groups according to their active cell phone use: group A: no use; group B: <2 h/day; group C: 2-4 h/day; and group D: >4 h/day. INTERVENTION(S): None. MAIN OUTCOME MEASURE(S): Sperm parameters (volume, liquefaction time, pH, viscosity, sperm count, motility, viability, and morphology). RESULT(S): The comparisons of mean sperm count, motility, viability, and normal morphology among four different cell phone user groups were statistically significant. Mean sperm motility, viability, and normal morphology were significantly different in cell phone user groups within two sperm count groups. The laboratory values of the above four sperm parameters decreased in all four cell phone user groups as the duration of daily exposure to cell phones increased. CONCLUSION(S): Use of cell phones decrease the semen quality in men by decreasing the sperm count, motility, viability, and normal morphology. The decrease in sperm parameters was dependent on the duration of daily exposure to cell phones and independent of the initial semen quality.

Agarwal A, Desai NR, Makker K, Varghese A, Mouradi R, Sabanegh E, Sharma R. Effects of radiofrequency electromagnetic waves (RF-EMW) from cellular phones on human ejaculated semen: an in vitro pilot study. Fertil Steril. 2008 Sep 18. [Epub ahead of print]

OBJECTIVE: To evaluate effects of cellular phone radiofrequency electromagnetic waves (RF-EMW) during talk mode on unprocessed (neat) ejaculated human semen. DESIGN: Prospective pilot study. SETTING: Center for reproductive medicine laboratory in tertiary hospital setting. SAMPLES: Neat semen samples from normal healthy donors ($n = 23$) and infertile patients ($n = 9$). INTERVENTION(S): After liquefaction, neat semen samples were divided into two aliquots. One aliquot (experimental) from each patient was exposed to cellular phone radiation (in talk mode) for 1 h, and the second aliquot (unexposed) served as the control sample under identical conditions. MAIN OUTCOME MEASURE(S): Evaluation of sperm parameters (motility, viability), reactive oxygen species (ROS), total antioxidant capacity (TAC) of semen, ROS-TAC score, and sperm DNA damage. RESULT(S): Samples exposed to RF-EMW showed a significant decrease in sperm motility and viability, increase in ROS level, and decrease in ROS-TAC score. Levels of TAC and DNA damage showed no significant differences from the unexposed group. CONCLUSION(S): Radiofrequency electromagnetic waves emitted from cell phones may lead to oxidative stress in human semen. We speculate that keeping the cell phone in a trouser pocket in talk mode may negatively affect spermatozoa and impair male fertility.

Aitken RJ, Bennetts LE, Sawyer D, Wiklendt AM, King BV. Impact of radio frequency electromagnetic radiation on DNA integrity in the male germline. International Journal of Andrology 28:171-179, 2005.

Concern has arisen over human exposures to radio frequency electromagnetic radiation (RFEMR), including a recent report indicating that regular mobile phone use can negatively impact upon human semen quality. These effects would be particularly serious if the biological effects of RFEMR included the induction of DNA damage in male germ cells. In this study, mice were exposed to 900 MHz RFEMR at a specific absorption rate of approximately 90 mW/kg inside a waveguide for 7 days at 12 h per day. Following exposure, DNA damage to caudal epididymal spermatozoa was assessed by quantitative PCR (QPCR) as well as alkaline and pulsed-field gel electrophoresis. The treated mice were overtly normal and all assessment criteria, including sperm number, morphology and vitality were not significantly affected. Gel electrophoresis revealed no gross evidence of increased single- or double-DNA strand breakage in spermatozoa taken from treated animals. However, a detailed analysis of DNA integrity using QPCR revealed statistically significant damage

to both the mitochondrial genome ($p < 0.05$) and the nuclear β -globin locus ($p < 0.01$). This study suggests that while RFEMR does not have a dramatic impact on male germ cell development, a significant genotoxic effect on epididymal spermatozoa is evident and deserves further investigation.

Aksen F, Dasdag S, Akdag MZ, Askin M, Dasdag MM. The effects of whole body cell phone exposure on the T1 relaxation times and trace elements in the serum of rats. *Electromag. Biol. Med.* 23:7-11, 2004.

The objective of this study was to investigate the effects of radiofrequency radiation emitted from cellular phones on: (1) trace elements such as manganese, iron, copper, zinc, (2) T1 relaxation times in serum, and (3) rectal temperature of rats exposed to microwave radiation emitted from cellular phones. Sixteen Sprague–Dawley rats were separated into two groups of eight, one sham-exposed (control) and one exposed (experimental). The rats were confined in Plexiglas cages and a cellular phone was placed 0.5 cm under the cage. For the experimental group, cellular phones were activated 20 min per day, 7 days a week, for 1 month. For the control group, a cellular phone placed beneath the cage for 20 min a day was turned off. Rectal temperatures were measured weekly. For 250-mW-radiated powers, the whole body average specified absorption rate (SAR) (rms) is 0.52 W/kg and 1-g-averaged peak SAR (rms) is 3.13 W/kg. The Mann-Whitney U test was used for statistical comparisons of groups. T1 relaxation time and the values of iron and copper in the serum of the experimental group were not changed compared to the control group ($p > 0.05$). However, manganese and zinc values in the serum of the experimental group were significantly different from the control group ($p < 0.05$). The difference in rectal temperature measured before and after exposure in the experimental groups was not statistically different from control ($p > 0.05$).

Aksoy U, Sahin S, Ozkoc S, Ergor G. The effect of electromagnetic waves on the growth of *Entamoeba histolytica* and *Entamoeba dispar*. *Saudi Med J.* 26(9):1388-1390, 2005.

OBJECTIVE: The aim of this study was to investigate the influence of electromagnetic radiation of a digital Global System for Mobile Communication mobile telephone (900 MHz) on *Entamoeba histolytica* (*E. histolytica*) and *Entamoeba dispar* (*E. dispar*) (cysts or trophozoites, or both) in a 24-hour period. **METHODS:** This study was carried out from April 2004 to May 2004 at the Department of Parasitology, Medical Faculty of Dokuz Eylul University in Izmir, Turkey. The cultivated isolate tubes, which were exposed to electromagnetic field at 37°C, were evaluated as study group, whereas the tubes without exposure were assessed as control group. Finally, only living parasites in all tubes were counted using a hemacytometer. The effect of the temperature was evaluated for both control and study groups. **RESULTS:** The influence of electromagnetic field and temperature was assessed separately for the study group. The parasite number of *E. histolytica* decreased after exposure at 37°C and room temperature ($p=0.009$) compared to the decrease in the control group ($p=0.009$). The parasite number of *E. dispar* also decreased after exposure at 37°C and room temperature ($p=0.009$). In comparison to control tubes, this was a significant decrease ($p=0.008$). In the case of exposure of *E. histolytica* the results did not reveal any significant difference between temperature degrees to magnetic field ($p=0.459$) and *E. dispar* ($p=0.172$). **CONCLUSION:** Our findings show that exposure to electromagnetic field for a certain period of time may cause damage that can lead to death in single-cell organisms.

Al-Dousary SH Mobile phone induced sensorineural hearing loss. *Saudi Med J.* 28(8):1283-1286, 2007.

.The increased use of mobile phones worldwide has focused interest on the biological effects and possible health outcomes of exposure to radiofrequency fields from mobile phones, and their base stations. Various reports suggest that mobile phone use can cause health problems like fatigue, headache, dizziness, tension, and sleep disturbances; however, only limited research data is available in medical literature regarding interaction between electromagnetic fields emitted by mobile phones and auditory function; and the possible impact on hearing. We report a case of sensorineural hearing loss due to Global System for Mobile Communications mobile phone use, in a 42-year-old male.

Al-Khlaiwi T, Meo SA. Association of mobile phone radiation with fatigue, headache, dizziness, tension and sleep disturbance in Saudi population. *Saudi Med J.* 25(6):732-736, 2004.

OBJECTIVE: The widespread use of mobile phones has been increased over the past decade; they are now an essential part of business, commerce and society. The use of mobile phones can cause health problems. Therefore, the aim of the present study is to investigate the association of using mobile phones with fatigue, headache, dizziness, tension and sleep disturbance in the Saudi population and provide health and social awareness in using these devices. **METHODS:** This study was conducted in the Department of Physiology, College of Medicine, King Saud University, Riyadh, Kingdom of Saudi Arabia during the year 2002 to 2003. In the present study, a total of 437 subjects (55.1% male and 39.9% female) were invited, they have and had been using mobile phones. A questionnaire was distributed regarding detailed history and association of mobile phones with health hazards. **RESULTS:** The results of the present study showed an association between the use of mobile phones and health hazards. The overall mean percentage for these clinical findings in all groups were headache (21.6%), sleep disturbance (4.%), tension (3.9%), fatigue (3%) and dizziness (2.4%). **CONCLUSION:** Based on the results of the present study, we conclude that the use of mobile phones is a risk factor for health hazards and suggest that long term or excessive use of mobile phones should be avoided by health promotion activities such as group discussions, public presentations and through electronic and print media sources.

Aly AA, Cheema MI, Tambawala M, Laterza R, Zhou E, Rathnabharathi K, Barnes FS. Effects of 900-MHz Radio Frequencies on the Chemotaxis of Human Neutrophils in Vitro. IEEE Transactions on Biomedical Engineering, 55(2): 795-797, 2008.

Summary: The effects of radio frequency (RF) fields on the ability of human neutrophils to follow concentration gradients of Cyclic Adenosine 3', 5'-Monophosphate (C-AMP) are reported. Blood from healthy adult donors was exposed in vitro to different temperatures and 900-MHz RF field at approximately 0.4 V/m. It was observed that the neutrophils' speed increased with increasing temperatures from 35 °C to 40 °C where it peaked and then decreased above 40 °C without RF exposure. When 900-MHz RF field was applied, the speed increased above the value observed at the same temperature, and the maximum speed exceeded that measured value at any temperature by approximately 50%. The calculated temperature change resulting from the RF exposure was less than one microdegree. The direction of motion changed from along the concentration gradient and the electrical field lines to motion at right angles to the concentration gradient and the electric field. The average time for the neutrophils to respond to the effect of RF radiation was about 2.5 min.

Ammari M, Brillaud E, Gamez C, Lecomte A, Sakly M, Abdelmelek H, de Seze R. Effect of a chronic GSM 900MHz exposure on glia in the rat brain. Biomed Pharmacother. 62(4):273-81, 2008.

Extension of the mobile phone technology raises concern about the health effects of 900MHz microwaves on the central nervous system (CNS). In this study we measured GFAP expression using immunocytochemistry method, to evaluate glial evolution 10 days after a chronic exposure (5 days a week for 24 weeks) to GSM signal for 45min/day at a brain-averaged specific absorption rate (SAR)=1.5W/kg and for 15min/day at a SAR=6W/kg in the following rat brain areas: prefrontal cortex (PFCx), caudate putamen (Cpu), lateral globus pallidus of striatum (LGP), dentate gyrus of hippocampus (DG) and cerebellum cortex (CCx). In comparison to sham or cage control animals, rats exposed to chronic GSM signal at 6W/kg have increased GFAP stained surface areas in the brain (p<0.05). But the chronic exposure to GSM at 1.5W/kg did not increase GFAP expression. Our results indicated that chronic exposure to GSM 900MHz microwaves (SAR=6W/kg) may induce persistent astroglia activation in the rat brain (sign of a potential gliosis).

Anane R, Geffard M, Taxile M, Bodet D, Billaudel B, Dulou PE, Veyret B. Effects of GSM-900 microwaves on the experimental allergic encephalomyelitis (EAE) rat model of multiple sclerosis. Bioelectromagnetics 24(3):211-213, 2003.

The effects of acute exposure to GSM-900 microwaves (900 MHz, 217 Hz pulse modulation) on the clinical parameters of the acute experimental allergic encephalomyelitis (EAE) model in rats were investigated in two independent experiments: rats were either habituated or nonhabituated to the exposure restrainers. EAE was induced with a mixture of myelin basic protein and Mycobacterium tuberculosis. Female Lewis rats were divided into cage control, sham exposed, and two groups exposed either at 1.5 or 6.0 W/kg local specific absorption rate (SAR averaged over the brain) using a loop

antenna placed over their heads. There was no effect of a 21-day exposure (2 h/day) on the onset, duration, and termination of the EAE crisis.

Anane R, Dulou P-E, Taxile M, Geffard M, Crespeau F, Veyret B. Effects of GSM-900 Microwaves on DMBA-Induced Mammary Gland Tumors in Female Sprague-Dawley Rats. *Radiat Res* 160:492–497, 2003.

The aim of this investigation was to test the hypothesis that sub-chronic whole-body exposure to GSM-900 microwaves had an effect on tumor promotion and progression. Mammary tumors were induced by ingestion of a single 10-mg dose of 7,12-dimethylbenz(a)anthracene (DMBA) in female Sprague-Dawley rats (Ico:OFA-SD; IOPS Caw). In two independent experiments, DMBA-treated animals were divided into four groups: sham-exposed (16) and exposed (three groups of 16 animals). The specific absorption rates (SARs), averaged over the whole body, were 3.5, 2.2 and 1.4 W/kg in the first experiment (May–July) and 1.4, 0.7 and 0.1 W/kg in the second experiment (September–November). Exposure started 10 days after DMBA treatment and lasted 2 h/day, 5 days/week for 9 weeks. Animals were exposed to plane waves with the electric field parallel to the long axis of the animals. Body weight and the number, location and size of the tumors were recorded at regular intervals. Rats were killed humanely 3 weeks after the end of exposure. The results are negative in terms of latency, multiplicity and tumor volume. With regard to tumor incidence, in the first experiment there was an increase in the rate of incidence at 1.4 W/kg but less at 2.2 W/kg and none at 3.5 W/kg. Overall, these results, which are rather inconsistent, do not bring new evidence of a co-promoting effect of exposure to GSM-900 signals using the DMBA rat model.

Andrzejak R, Poreba R, Poreba M, Derkacz A, Skalik R, Gac P, Beck B, Steinmetz-Beck A, Pilecki W. The influence of the call with a mobile phone on heart rate variability parameters in healthy volunteers. *Ind Health*. 46(4):409-417, 2008.

It is possible that electromagnetic field (EMF) generated by mobile phones (MP) may have an influence on the autonomic nervous system (ANS) and modulates the function of circulatory system. The aim of the study was to estimate the influence of the call with a mobile phone on heart rate variability (HRV) in young healthy people. The time and frequency domain HRV analyses were performed to assess the changes in sympathovagal balance in a group of 32 healthy students with normal electrocardiogram (ECG) and echocardiogram at rest. The frequency domain variables were computed: ultra low frequency (ULF) power, very low frequency (VLF) power, low frequency (LF) power, high frequency (HF) power and LF/HF ratio was determined. ECG Holter monitoring was recorded in standardized conditions: from 08:00 to 09:00 in the morning in a sitting position, within 20 min periods: before the telephone call (period I), during the call with use of mobile phone (period II), and after the telephone call (period III). During 20 min call with a mobile phone time domain parameters such as standard deviation of all normal sinus RR intervals (SDNN [ms]--period I: 73.94+/-25.02, period II: 91.63+/-35.99, period III: 75.06+/-27.62; I-II: p<0.05, II-III: p<0.05) and standard deviation of the averaged normal sinus RR intervals for all 5-mm segments (SDANN [ms]--period I: 47.78+/-22.69, period II: 60.72+/-27.55, period III: 47.12+/-23.21; I-II: p<0.05, II-III: p<0.05) were significantly increased. As well as very low frequency (VLF [ms²]--period I: 456.62+/-214.13, period II: 566.84+/-216.99, period III: 477.43+/-203.94; I-II: p<0.05), low frequency (LF [ms(2)]--period I: 607.97+/-201.33, period II: 758.28+/-307.90, period III: 627.09+/-220.33; I-II: p<0.01, II-III: p<0.05) and high frequency (HF [ms(2)]--period I: 538.44+/-290.63, period II: 730.31+/-445.78, period III: 590.94+/-301.64; I-II: p<0.05) components were the highest and the LF/HF ratio (period I: 1.48+/-0.38, period II: 1.16+/-0.35, period III: 1.46+/-0.40; I-II: p<0.05, II-III: p<0.05) was the lowest during a call with a mobile phone. The tone of the parasympathetic system measured indirectly by analysis of heart rate variability was increased while sympathetic tone was lowered during the call with use of a mobile phone. It was shown that the call with a mobile phone may change the autonomic balance in healthy subjects. Changes in heart rate variability during the call with a mobile phone could be affected by electromagnetic field but the influence of speaking cannot be excluded.

Antonopoulos A, Eisenbrandt H, Obe G, Effects of high-frequency electromagnetic fields on human lymphocytes in vitro. *Mutat Res* 395(2-3): 209-214, 1997.

Human peripheral lymphocytes were incubated in the presence of high-frequency electromagnetic fields of 380, 900 and 1800 MHz. The measured endpoints were cell cycle progression and the frequencies of sister-chromatid exchanges. No

differences between treated and control cultures could be found.

Arai N, Enomoto H, Okabe S, Yuasa K, Kamimura Y, Ugawa Y. Thirty minutes mobile phone use has no short-term adverse effects on central auditory pathways. *Clin Neurophysiol.* 114(8):1390-394, 2003.

OBJECTIVE: To investigate whether pulsed high-frequency electromagnetic field (pulsed EM field) emitted by a mobile phone for 30 min has short-term adverse effects on the human central auditory system. **METHODS:** We studied the auditory brainstem response (ABR), the ABR recovery function and middle latency response (MLR) before and after using a mobile phone for 30 min in 15 normal hearing volunteers. **RESULTS:** None of the 3 measures were affected by exposure to pulsed EM field emitted by a mobile phone for 30 min. **CONCLUSIONS:** Based on the ABR and MLR methods utilized in the study, we conclude that 30 min mobile phone use has no short-term adverse effects on the human auditory system.

Aran JM, Carrere N, Chalan Y, Dulou PE, Larrieu S, Letenneur L, Veyret B, Dulon D. Effects of exposure of the ear to GSM microwaves: in vivo and in vitro experimental studies. *Int J Audiol.* 43(9):545-554, 2004.

The effects of mobile phone (GSM) microwaves on the ears of guinea pigs were investigated in two in vivo experiments and one in vitro experiment. In the first experiment, three groups of eight guinea pigs had their left ear exposed for 1 h/day, 5 days/week, for 2 months, to GSM microwaves (900 MHz. GSM modulated) at specific absorption rates (SARs) of 1, 2 and 4 W/kg respectively, and a fourth group was sham-exposed. Distortion-product otoacoustic emissions (DPOAEs) were measured for each ear before exposure, at the end of the 2-month exposure period, and 2 months later. In the second experiment, the same protocol was applied to eight sham-exposed and 16 exposed guinea pigs at 4W/kg, but the auditory brainstem response (ABR) thresholds were monitored. Repeated-measures ANOVA showed no difference in DPOAE amplitudes or in ABR thresholds between the exposed and non-exposed ears and between the sham-exposed and exposed groups. In the course of the second experiment, acute effects were also investigated by measuring once, in all animals, ABR thresholds just before and just after the 1-h exposure: no statistically significant difference was observed. In vitro, the two organs of Corti (OCs) of newborn rats (n=15) were isolated and placed in culture. For each animal, one OC was exposed for 24-48 h to 1 W/kg GSM microwaves, and the other was sham-exposed. After 2-3 days of culture, all OCs were observed under light microscopy. They all appeared normal to naive observers at this stage of development. These results provided no evidence that microwave radiation, at the levels produced by mobile phones, caused damage to the inner ear or the auditory pathways in our experimental animals.

Arnetz BB, Wiholm C, Kuster N, Hillert L, Moffat SD. EXPLORING EXPOSURE TO MOBILE PHONE ELECTROMAGNETIC FIELDS AND PSYCHOPHYSIOLOGICAL AND SELF-RATED SYMPTOMS. *Psychosom Med.* 2009 Jan 5. [Epub ahead of print] (no abstract available)

Arns M, Van Luijtelaar G, Sumich A, Hamilton R, Gordon E. Electroencephalographic, personality, and executive function measures associated with frequent mobile phone use. *Int J Neurosci.* 117(9):1341-1360, 2007.

The present study employs standardized data acquired from the Brain Resource International Database to study the relationship between mobile phone usage, personality, and brain function (n = 300). Based on the frequency and duration of mobile phone usage, three groups were formed. The findings suggest a subtle slowing of brain activity related to mobile phone use that is not explained by differences in personality. These changes are still within normal physiological ranges. Better executive function in mobile phone users may reflect more focused attention, possibly associated with a cognitive training effect (i.e., frequently making phone calls in distracting places), rather than a direct effect of mobile phone use on cognition.

Augner C, Florian M, Pauser G, Oberfeld G, Hacker GW. GSM base stations: Short-term effects on well-being. Bioelectromagnetics. 2008 Sep 19. [Epub ahead of print]

The purpose of this study was to examine the effects of short-term GSM (Global System for Mobile Communications) cellular phone base station RF-EMF (radiofrequency electromagnetic fields) exposure on psychological symptoms (good mood, alertness, calmness) as measured by a standardized well-being questionnaire. Fifty-seven participants were selected and randomly assigned to one of three different exposure scenarios. Each of those scenarios subjected participants to five 50-min exposure sessions, with only the first four relevant for the study of psychological symptoms. Three exposure levels were created by shielding devices in a field laboratory, which could be installed or removed during the breaks between sessions such that double-blinded conditions prevailed. The overall median power flux densities were 5.2 microW/m(2) during "low," 153.6 microW/m(2) during "medium," and 2126.8 microW/m(2) during "high" exposure sessions. For scenario HM and MH, the first and third sessions were "low" exposure. The second session was "high" and the fourth was "medium" in scenario HM; and vice versa for scenario MH. Scenario LL had four successive "low" exposure sessions constituting the reference condition. Participants in scenarios HM and MH (high and medium exposure) were significantly calmer during those sessions than participants in scenario LL (low exposure throughout) ($P = 0.042$). However, no significant differences between exposure scenarios in the "good mood" or "alertness" factors were obtained. We conclude that short-term exposure to GSM base station signals may have an impact on well-being by reducing psychological arousal. Bioelectromagnetics, 2008 (c) 2008 Wiley-Liss, Inc.

Auvinen A, Hietanen M, Luukkonen R, Koskela R-S, Brain Tumors and Salivary Gland Cancers Among Cellular Telephone Users *Epidemiology* 13:356-359, 2002.

Background. Possible risk of cancer associated with use of cellular telephones has lately been a subject of public debate. Methods. We conducted a register-based, case-control study on cellular phone use and cancer. The study subjects were all cases of brain tumor ($N = 398$) and salivary gland cancer ($N = 34$) diagnosed in Finland in 1996, with five controls per case. Results. Cellular phone use was not associated with brain tumors or salivary gland cancers overall, but there was a weak association between gliomas and analog cellular phones. Conclusions. A register-based approach has limited value in risk assessment of cellular phone use owing to lack of information on exposure.

Ayata A, Mollaoglu H, Yilmaz HR, Akturk O, Ozguner F, Altuntas I. Oxidative stress-mediated skin damage in an experimental mobile phone model can be prevented by melatonin. *J Dermatol.* 31(11):878-883, 2004.

Most mobile phones emit 900 MHz of radiation that is mainly absorbed by the external organs. The effects of 900 MHz of radiation on fibrosis, lipid peroxidation, and anti-oxidant enzymes and the ameliorating effects of melatonin (Mel) were evaluated in rat skin. Thirty Wistar-Albino rats were used in the study. The experimental groups were the control group, the irradiated group (IR), and the irradiated+Mel treated group (IR+Mel). A dose of 900 MHz, 2 W radiation was applied to the IR group every day for 10 days (30 min/day). The IR+Mel group received 10 mg/kg/day melatonin in tap water for 10 days before the irradiation. At the end of the 10th day, a skin specimen was excised from the thoracoabdominal area. The levels of malondialdehyde (MDA) and hydroxypyroline and the activities of superoxide dismutase (SOD), glutathione peroxidase (GSH-Px), and catalase (CAT) were studied in the skin samples. MDA and hydroxypyroline levels and activities of CAT and GSH-Px were increased significantly in the IR group compared to the control group ($p < 0.05$) and decreased significantly in the IR+Mel group ($p < 0.05$). SOD activity was decreased significantly in the IR group and this decrease was not prevented by the Mel treatment. These results suggest that rats irradiated with 900 MHz suffer from increased fibrosis and lipid peroxidation (LPO). Mel treatment can reduce the fibrosis and LPO caused by radiation.

Bakos J, Kubinyi G, Sinay H, Thuroczy G. GSM modulated radiofrequency radiation does not affect 6-sulfatoxymelatonin excretion of rats. *Bioelectromagnetics* 24(8):531-534, 2003.

In this study, the effect of exposure to 900 and 1800 MHz GSM-like radiofrequency radiation upon the urinary 6-sulfatoxymelatonin (6SM) excretion of adult male Wistar rats was studied. Seventy-two rats were used in six independent experiments, three of which were done with 900 MHz and the other three with 1800 MHz. The exposures were performed

in a gigahertz transverse electromagnetic mode (GTEM) cell. The power densities of radiation were 100 and 20 microW/cm² at 900 and 1800 MHz frequency, respectively. The carrier frequency was modulated with 218 Hz, as in the GSM signal. The animals were exposed for 2 h between 8:00 AM and noon daily during the 14 day exposure period. The urine of rats was collected from 12:00 AM to 8:00 AM, collecting from exposed and control animal groups on alternate days. The urinary 6SM concentration was measured by (125)I radioimmunoassay and was referred to creatinine. The combined results of three experiments done with the same frequency were statistically analyzed. Statistically significant changes in the 6SM excretion of exposed rats (n = 18) compared to control group (n = 18) were not found either at 900 or 1800 MHz.

Balci M, Devrim E, Durak I. Effects of mobile phones on oxidant/antioxidant balance in cornea and lens of rats. *Curr Eye Res.* 32(1):21-25, 2007.

Purpose: To investigate the effects of mobile-phone-emitted radiation on the oxidant/antioxidant balance in corneal and lens tissues and to observe any protective effects of vitamin C in this setting. Methods: Forty female albino Wistar rats were assigned to one of four groups containing 10 rats each. One group received a standardized daily dose of mobile phone radiation for 4 weeks. The second group received this same treatment along with a daily oral dose of vitamin C (250 mg/kg). The third group received this dose of vitamin C alone, while the fourth group received standard laboratory care and served as a control. In corneal and lens tissues, malondialdehyde (MDA) levels and activities of superoxide dismutase (SOD), glutathione peroxidase (GSH-Px), and catalase (CAT) were measured with spectrophotometric methods. Results: In corneal tissue, MDA level and CAT activity significantly increased in the mobile phone group compared with the mobile phone plus vitamin C group and the control group ($p < 0.05$), whereas SOD activity was significantly decreased ($p < 0.05$). In the lens tissues, only the MDA level significantly increased in the mobile phone group relative to mobile phone plus vitamin C group and the control groups ($p < 0.05$). In lens tissue, significant differences were not found between the groups in terms of SOD, GSH-Px, or CAT ($p > 0.05$). Conclusions: The results of this study suggest that mobile telephone radiation leads to oxidative stress in corneal and lens tissues and that antioxidants such as vitamin C can help to prevent these effects

Balik HH, Turgut-Balik D, Balikci K, Ozcan IC. Some ocular symptoms and sensations experienced by long term users of mobile phones. *Pathol Biol (Paris)*. 53(2):88-91, 2005.

In this study, a survey was conducted to investigate the possible effects of long term usage of mobile phone (MP) on eyes. The studied symptoms are blurring of vision, redness on the eyes, vision disturbance, secretion of the eyes, inflammation in the eyes and lacrimation of the eyes. There is no effect on redness on the eyes and vision disturbance, but some statistical evidences are found that MP may cause blurring of vision, secretion of the eyes, inflammation in the eyes and lacrimation of the eyes. These results suggest an awareness of the symptoms and sensations.

Balikci K, Cem Ozcan I, Turgut-Balik D, Balik HH. A survey study on some neurological symptoms and sensations experienced by long term users of mobile phones. *Pathol Biol (Paris)*. 53(1):30-34, 2005.

A survey study was conducted to investigate the possible effects of mobile phone on headache, dizziness, extreme irritation, shaking in the hands, speaking falteringly, forgetfulness, neuro-psychological discomfort, increase in the carelessness, decrease of the reflex and clicking sound in the ears. There is no effect on dizziness, shaking in hands, speaking falteringly and neuro-psychological discomfort, but some statistical evidences are found that mobile phone may cause headache, extreme irritation, increase in the carelessness, forgetfulness, decrease of the reflex and clicking sound in the ears.

Bamiou DE, Ceranic B, Cox R, Watt H, Chadwick P, Luxon LM. Mobile telephone use effects on peripheral audiovestibular function: A case-control study. *Bioelectromagnetics*. 2007 Oct 10; [Epub ahead of print]

Low level radio-frequency (RF) signals may produce disorientation, headache and nausea. This double blind study tested nine case-subjects, who complained of various symptoms after prolonged mobile telephone use and 21 control subjects.

Each subject underwent a series of trials, in which a dummy mobile telephone exposure system was held to each ear for 30 min in (a) pulsed, (b) continuous RF emission or, (c) no emission test modes. In the active pulsed and continuous modes the same mean power as the output of a typical handset was delivered at a carrier frequency of 882 MHz and at a maximum specific absorption rate (SAR) value of 1.3 W kg⁻¹ (+/- 30%). In Experiment I (auditory), transient evoked otoacoustic emissions (TEOAE), which assess the outer hair cells in the inner ear, were conducted. In Experiment II (vestibular) the vestibulo-ocular reflex was recorded by video-oculography (VOG), at baseline and immediately post exposure. There were no significant TEOAE changes from baseline to post-exposure recording for any of the exposures and no significant differences in the TEOAEs' change from baseline to post exposure between cases and controls. The VOG did not identify any effect of the exposure on the vestibular end organ in either cases or controls. In conclusion, 30 min exposure to mobile phone RF did not show any immediate effects on vestibulocochlear function as measured by TEOAE and the VOR.

Barker AT, Jackson PR, Parry H, Coulton LA, Cook GG, Wood SM. The effect of GSM and TETRA mobile handset signals on blood pressure, catechol levels and heart rate variability. Bioelectromagnetics. 2007 May 7; [Epub ahead of print]

An acute rise in blood pressure has been reported in normal volunteers during exposure to signals from a mobile phone handset. To investigate this finding further we carried out a double blind study in 120 healthy volunteers (43 men, 77 women) in whom we measured mean arterial pressure (MAP) during each of six exposure sessions. At each session subjects were exposed to one of six different radio frequency signals simulating both GSM and TETRA handsets in different transmission modes. Blood catechols before and after exposure, heart rate variability during exposure, and post exposure 24 h ambulatory blood pressure were also studied. Despite having the power to detect changes in MAP of less than 1 mmHg none of our measurements showed any effect which we could attribute to radio frequency exposure. We found a single statistically significant decrease of 0.7 mmHg (95% CI 0.3-1.2 mmHg, P = .04) with exposure to GSM handsets in sham mode. This may be due to a slight increase in operating temperature of the handsets when in this mode. Hence our results have not confirmed the original findings of an acute rise in blood pressure due to exposure to mobile phone handset signals. In light of this negative finding from a large study, coupled with two smaller GSM studies which have also proved negative, we are of the view that further studies of acute changes in blood pressure due to GSM and TETRA handsets are not required.

Barteri M, Pala A, Rotella S. Structural and kinetic effects of mobile phone microwaves on acetylcholinesterase activity. *Biophys Chem*. 113(3):245-253, 2005.

The present study provides evidence that "in vitro" simple exposure of an aqueous solution of electric eel acetylcholinesterase (EeAChE; EC 3.1.1.7.) to cellular phone emission alters its enzymatic activity. This paper demonstrates, by combining different experimental techniques, that radio frequency (RF) radiations irreversibly affect the structural and biochemical characteristics of an important CNS enzyme. These results were obtained by using a commercial cellular phone to reproduce the reality of the human exposition. This experimental procedure provided surprising effects collected practically without experimental errors because they were obtained comparing native and irradiated sample of the same enzyme solution. Although these results cannot be used to conclude whether exposure to RF during the use of cellular phone can lead to any hazardous health effect, they may be a significant first step towards further verification of these effects on other "ex vivo" or "in vivo" biological systems.

Barth A, Winker R, Ponocny-Seliger E, Mayrhofer W, Ponocny I, Sauter C, Vana N. A meta-analysis for neurobehavioral effects due to electromagnetic field exposure emitted by GSM mobile phones. Occup Environ Med. 2007 Oct 10 [Epub ahead of print]

BACKGROUND AND OBJECTIVE: Numerous studies have investigated the potential effects of electromagnetic fields (EMFs) emitted by GSM mobile phones (~900 MHz to ~1800 MHz) on cognitive functioning, but results have been equivocal. In order to try and clarify this issue, the current study carried out a meta-analysis on nineteen experimental studies. **DESIGN:** meta-analysis **METHODS:** Nineteen studies were taken into consideration. Ten of them were included in the meta-analysis as they fulfil several minimum requirements; for example, single-blind or double-blind experimental

study design and documentation of means and standard deviation of the dependent variables. The meta-analysis aimed at comparing exposed with non-exposed subjects assuming that there is a common population effect so that one single effect size could be calculated. When homogeneity for single effect sizes was not given, an own population effect for each study and a distribution of population effects was assumed. **RESULTS:** Attention measured by the subtraction task seems to be affected in regard of decreased reaction time. Working memory measured by the N-back test seems to be affected too: Under condition 0-back target response time is lower under exposure, while under condition 2-back target response time increases. The number of errors under condition 2-back non-targets appears to be higher under exposure. **CONCLUSION:** Results of the meta-analysis suggest that EMFs may have a small impact on human attention and working memory.

Bartsch H, Bartsch C, Seebald E, Deerberg F, Dietz K, Vollrath L, Mecke D. Chronic Exposure to a GSM-like Signal (Mobile Phone) Does Not Stimulate the Development of DMBA-Induced Mammary Tumors in Rats: Results of Three Consecutive Studies. *Radiat Res* 157(2):183-190, 2002.

Certain epidemiological and experimental studies raised concerns about the safety of radiofrequency (RF) electromagnetic fields because of a possible increased risk of leukemia and lymphoma. In this study, an RF field used in mobile telecommunication was tested using 7,12-dimethylbenz[a]anthracene (DMBA)-induced mammary tumors in female Sprague-Dawley rats as a model for human breast cancer. Three experiments were carried out under strictly standardized conditions and were started on the same day of three consecutive years. The field consisted of a GSM-like signal (900 MHz pulsed at 217 Hz, pulse width 577 [μs]) of relatively low power flux density (100 [μW/cm²] [plus minus] 3 dB) and was applied continuously throughout each experiment to freely moving animals. The specific absorption rates averaged over the whole body were 17.5--70 mW/kg. The highest values in young animals were at or around the exposure limit permissible for the general public (i.e. 80 mW/kg). The animals were palpated weekly for the presence of mammary tumors and were killed humanely when tumors reached a diameter of 1--2 cm to allow a reliable histopathological classification and a distinction between malignant and benign subtypes. The overall results of the three studies are that there was no statistically significant effect of RF-field exposure on tumor latency and that the cumulative tumor incidence at the end of the experiment was unaffected as well. The risk ratios were 1.08 (95% CI: 0.91--1.29) and 0.96 (95% CI: 0.85--1.07) for benign and malignant tumors, respectively. These observations are in agreement with other published findings. In the first experiment, however, the median latency for the development of the first malignant tumor in each animal was statistically significantly extended for RF-field-exposed animals compared to controls (278 days compared to 145 days, *P* = 0.009). No such differences were detected in the two subsequent experiments. These results show that low-level RF radiation does not appear to possess carcinogenic or cancer-promoting effects on DMBA-induced mammary tumors. To explain the mechanisms underlying the different results obtained in the three experiments, a hypothesis is presented which is based upon the neuroendocrine control mechanisms involved in the promotion of DMBA-induced mammary tumors. Despite the apparent absence of stimulatory effects of low-level RF-field exposure on the development and growth of solid tumors, it will be necessary to verify these results for leukemias and lymphomas, which may have completely different biological control mechanisms.

Baste V, Riise T, Moen BE. Radiofrequency electromagnetic fields; male infertility and sex ratio of offspring. *Eur J Epidemiol*. 2008 Apr 16 [Epub ahead of print]

Concern is growing about exposure to electromagnetic fields and male reproductive health. The authors performed a cross-sectional study among military men employed in the Royal Norwegian Navy, including information about work close to equipment emitting radiofrequency electromagnetic fields, one-year infertility, children and sex of the offspring. Among 10,497 respondents, 22% had worked close to high-frequency aerials to a "high" or "very high" degree. Infertility increased significantly along with increasing self-reported exposure to radiofrequency electromagnetic fields. In a logistic regression, odds ratio (OR) for infertility among those who had worked closer than 10 m from high-frequency aerials to a "very high" degree relative to those who reported no work near high-frequency aerials was 1.86 (95% confidence interval (CI): 1.46-2.37), adjusted for age, smoking habits, alcohol consumption and exposure to organic solvents, welding and lead. Similar adjusted OR for those exposed to a "high", "some" and "low" degree were 1.93 (95% CI: 1.55-2.40), 1.52 (95% CI: 1.25-1.84), and 1.39 (95% CI: 1.15-1.68), respectively. In all age groups there were significant linear trends with higher prevalence of involuntary childlessness with higher self-reported exposure to radiofrequency fields. However, the degree of exposure to radiofrequency radiation and the number of children were not associated. For self-reported

exposure both to high-frequency aeriads and communication equipment there were significant linear trends with lower ratio of boys to girls at birth when the father reported a higher degree of radiofrequency electromagnetic exposure.

Batellier F, Couty I, Picard D, Brillard JP. Effects of exposing chicken eggs to a cell phone in "call" position over the entire incubation period. *Theriogenology*. 2008 Feb 4 [Epub ahead of print]

The aim of the present study was to assess the effects of exposing fertile chicken eggs to a cell phone repeatedly calling a ten-digit number at 3-min intervals over the entire period of incubation. A pre-experiment was performed first to adjust incubation conditions in an experimental chamber devoid of metallic content and without automatic turning until the overall performance of hatchability was reproducible in the absence of the cell phone. The experimental period consisted of a series of 4 incubations referred to as "replicates". For each replicate, one batch of 60 eggs was exposed to the immediate environment (≤ 25 cm) of a cell phone in the "call" position (exposed group), while another batch of 60 eggs, 1.5m away from the exposed group and also in the incubation chamber, was exposed to a similar cell phone in the "off" position (sham group). For each replicate, 2 other groups each of 60 eggs were also incubated, one in a standard mini-incubator ("Control I" group) and the second in a standard medium size incubator ("Control II" group). Temperature, relative humidity and electromagnetic fields in the experimental chamber were permanently monitored over the entire experiment. A significantly higher percentage of embryo mortality was observed in the "exposed" compared to the "sham" group in 2 of the 4 replicates ($p < .05$). In comparison with control groups, additional embryo mortality in the exposed group occurred mainly between Days 9 and 12 of incubation but a causal relationship between the intensity of the electric field and embryo mortality could not be established.

Beason RC, Semm P. Responses of neurons to an amplitude modulated microwave stimulus. *Neurosci Lett* 333(3):175-178, 2002.

In this study we investigated the effects of a pulsed radio frequency signal similar to the signal produced by global system for mobile communication telephones (900 MHz carrier, modulated at 217 Hz) on neurons of the avian brain. We found that such stimulation resulted in changes in the amount of neural activity by more than half of the brain cells. Most (76%) of the responding cells increased their rates of firing by an average 3.5-fold. The other responding cells exhibited a decrease in their rates of spontaneous activity. Such responses indicate potential effects on humans using hand-held cellular phones.

Belyaev IY, Hillert L, Protopopova M, Tamm C, Malmgren LO, Persson BR, Selivanova G, Harms-Ringdahl M. 915 MHz microwaves and 50 Hz magnetic field affect chromatin conformation and 53BP1 foci in human lymphocytes from hypersensitive and healthy persons. *Bioelectromagnetics*. 26(3):173-184, 2005.

We used exposure to microwaves from a global system for mobile communication (GSM) mobile phone (915 MHz, specific absorption rate (SAR) 37 mW/kg) and power frequency magnetic field (50 Hz, 15 μ T peak value) to investigate the response of lymphocytes from healthy subjects and from persons reporting hypersensitivity to electromagnetic field (EMF). The hypersensitive and healthy donors were matched by gender and age and the data were analyzed blind to treatment condition. The changes in chromatin conformation were measured with the method of anomalous viscosity time dependencies (AVTD). 53BP1 protein, which has been shown to colocalize in foci with DNA double strand breaks (DSBs), was analyzed by immunostaining in situ. Exposure at room temperature to either 915 MHz or 50 Hz resulted in significant condensation of chromatin, shown as AVTD changes, which was similar to the effect of heat shock at 41 degrees C. No significant differences in responses between normal and hypersensitive subjects were detected. Neither 915 MHz nor 50 Hz exposure induced 53BP1 foci. On the contrary, a distinct decrease in background level of 53BP1 signaling was observed upon these exposures as well as after heat shock treatments. This decrease correlated with the AVTD data and may indicate decrease in accessibility of 53BP1 to antibodies because of stress-induced chromatin condensation. Apoptosis was determined by morphological changes and by apoptotic fragmentation of DNA as analyzed by pulsed-field gel electrophoresis (PFGE). No apoptosis was induced by exposure to 50 Hz and 915 MHz microwaves. In conclusion, 50 Hz magnetic field and 915 MHz microwaves under specified conditions of exposure induced comparable responses in lymphocytes from healthy and hypersensitive donors that were similar but not identical to stress response induced by heat shock.

Belyaev IY, Koch CB, Terenius O, Roxstrom-Lindquist K, Malmgren LO, H Sommer W, Salford LG, Persson BR. Exposure of rat brain to 915 MHz GSM microwaves induces changes in gene expression but not double stranded DNA breaks or effects on chromatin conformation. Bioelectromagnetics. 2006 Mar 1; [Epub ahead of print]

We investigated whether exposure of rat brain to microwaves (MWs) of global system for mobile communication (GSM) induces DNA breaks, changes in chromatin conformation and in gene expression. An exposure installation was used based on a test mobile phone employing a GSM signal at 915 MHz, all standard modulations included, output power level in pulses 2 W, specific absorption rate (SAR) 0.4 mW/g. Rats were exposed or sham exposed to MWs during 2 h. After exposure, cell suspensions were prepared from brain samples, as well as from spleen and thymus. For analysis of gene expression patterns, total RNA was extracted from cerebellum. Changes in chromatin conformation, which are indicative of stress response and genotoxic effects, were measured by the method of anomalous viscosity time dependencies (AVTD). DNA double strand breaks (DSBs) were analyzed by pulsed-field gel electrophoresis (PFGE). Effects of MW exposure were observed on neither conformation of chromatin nor DNA DSBs. Gene expression profiles were obtained by Affymetrix U34 GeneChips representing 8800 rat genes and analyzed with the Affymetrix Microarray Suite (MAS) 5.0 software. In cerebellum from all exposed animals, 11 genes were upregulated in a range of 1.34-2.74 fold and one gene was downregulated 0.48-fold ($P < .0025$). The induced genes encode proteins with diverse functions including neurotransmitter regulation, blood-brain barrier (BBB), and melatonin production. The data shows that GSM MWs at 915 MHz did not induce PFGE-detectable DNA double stranded breaks or changes in chromatin conformation, but affected expression of genes in rat brain cells

Belyaev IY, Marková E, Hillert L, Malmgren LO, Persson BR. Microwaves from UMTS/GSM mobile phones induce long-lasting inhibition of 53BP1/gamma-H2AX DNA repair foci in human lymphocytes. Bioelectromagnetics. 2008 Oct 6. [Epub ahead of print]

We have recently described frequency-dependent effects of mobile phone microwaves (MWs) of global system for mobile communication (GSM) on human lymphocytes from persons reporting hypersensitivity to electromagnetic fields and healthy persons. Contrary to GSM, universal global telecommunications system (UMTS) mobile phones emit wide-band MW signals. Hypothetically, UMTS MWs may result in higher biological effects compared to GSM signal because of eventual "effective" frequencies within the wideband. Here, we report for the first time that UMTS MWs affect chromatin and inhibit formation of DNA double-strand breaks co-localizing 53BP1/gamma-H2AX DNA repair foci in human lymphocytes from hypersensitive and healthy persons and confirm that effects of GSM MWs depend on carrier frequency. Remarkably, the effects of MWs on 53BP1/gamma-H2AX foci persisted up to 72 h following exposure of cells, even longer than the stress response following heat shock. The data are in line with the hypothesis that the type of signal, UMTS MWs, may have higher biological efficiency and possibly larger health risk effects compared to GSM radiation emissions. No significant differences in effects between groups of healthy and hypersensitive subjects were observed, except for the effects of UMTS MWs and GSM-915 MHz MWs on the formation of the DNA repair foci, which were different for hypersensitive ($P < 0.02[53BP1]/0.01[\text{gamma-H2AX}]$) but not for control subjects ($P > 0.05$). The non-parametric statistics used here did not indicate specificity of the differences revealed between the effects of GSM and UMTS MWs on cells from hypersensitive subjects and more data are needed to study the nature of these differences.

Berg G, Spallek J, Schuz J, Schlehofer B, Bohler E, Schlaefer K, Hettinger I, Kunna-Grass K, Wahrendorf J, Blettner M. Occupational Exposure to Radio Frequency/Microwave Radiation and the Risk of Brain Tumors: Interphone Study Group, Germany. *Am J Epidemiol*. 164(6):538-548, 2006.

It is still under debate whether occupational exposure to radio frequency/microwave electromagnetic fields (RF/MW-EMF) contributes to the development of brain tumors. This analysis examined the role of occupational RF/MW-EMF exposure in the risk of glioma and meningioma. A population-based, case-control study including 381 meningioma cases, 366 glioma cases, and 1,494 controls aged 30-69 years was performed in three German regions in 2000-2003. An exposure matrix for occupational activity was constructed by using information on RF/MW-EMF exposure collected in a computer-assisted personal interview. "High" exposure was defined as an occupational exposure that may exceed the RF/MW-EMF exposure limits for the general public recommended by the International Commission on Non-Ionizing Radiation Protection. Multiple conditional logistic regressions were performed separately for glioma and meningioma. No

significant association between occupational exposure to RF/MW-EMF and brain tumors was found. For glioma, the adjusted odds ratio for highly exposed persons compared with persons not highly exposed was 1.21 (95% confidence interval: 0.69, 2.13); for meningioma, it was 1.34 (95% confidence interval: 0.64, 2.81). However, the slight increase in risk observed with increasing duration of exposure merits further research with larger sample sizes.

Bergamaschi A, Magrini A, Ales G, Coppetta L, Somma G. Are thyroid dysfunctions related to stress or microwave exposure (900 MHz)? *Int J Immunopathol Pharmacol.* 17(2 Suppl):31-36, 2004.

In the last decade, numerous scientific evidence suggested possible adverse health effects from exposure to electromagnetic fields (EMF's) and the use of mobile phones. According to some studies EMF induced changes of trans-membrane Ca++ flux may lead to altered metabolism and/or secretion of neurohormones including TSH, ACTH, GH, prolactin and melatonin. The aim of this research was to analyse the effects of mobile phone use on thyroid function and to evaluate the possible role of occupational stress. 2598 employees (1355 men and 1243 women) with different duties (vendors, operators and network technicians) were included in the study. Exposure to EMF's, generated by mobile phones, was assessed both by submitting a questionnaire directly to the employees and acquiring data regarding conversation times. The workers were divided into three groups on the basis of their personal mobile phone use. Moreover, a group of 160 workers with TSH values below 0.4 UI/l was characterized. No statistically significant difference regarding TSH values below 0.4 UI/l was observed among workers with different duties but there was a greater prevalence of subjects with low TSH values among 192 employees with more than 33 hrs/month conversation time; this difference was statistically significant ($p < 0.05$). On the basis of our data, it is not possible to establish whether this result is determined by exposure to EMF's from mobile phones or by the stress of using these instruments.

Berg-Beckhoff G, Blettner M, Kowall B, Breckenkamp J, Schlehofer B, Schmiedel S, Bornkessel C, Reis U, Potthoff P, Schuz J Mobile phone base stations and adverse health effects: phase 2 of a cross-sectional study with measured radio frequency electromagnetic fields. *Occup Environ Med* 66:124-130, 2009.

ABSTRACT

Objective: The aim of the cross-sectional study was to test the hypothesis that exposure to continuous low-level radio frequency electromagnetic fields (RF-EMFs) emitted from mobile phone base stations was related to various health disturbances.

Methods: For the investigation people living mainly in urban regions were selected from a nationwide study in 2006. In total, 3526 persons responded to a questionnaire (response rate 85%). For the exposure assessment a dosimeter measuring different RF-EMF frequencies was used. Participants answered a postal questionnaire on how mobile phone base stations affected their health and they gave information on sleep disturbances, headaches, health complaints and mental and physical health using standardised health questionnaires. Information on stress was also collected. Multiple linear regression models were used with health outcomes as dependent variables ($n=1326$).

Results: For the five health scores used, no differences in their medians were observed for exposed versus nonexposed participants. People who attributed adverse health effects to mobile phone base stations reported significantly more sleep disturbances and health complaints, but they did not report more headaches or less mental and physical health. Individuals concerned about mobile phone base stations did not have different wellbeing scores compared with those who were not concerned.

Conclusions: In this large population-based study, measured RF-EMFs emitted from mobile phone base stations were not associated with adverse health effects.

Besset A, Espa F, Dauvilliers Y, Billiard M, de Seze R. No effect on cognitive function from daily mobile phone use. *Bioelectromagnetics.* 26(2):102-108, 2005.

The increasing use of mobiles phones (MP) has raised the problem of the effects of daily electromagnetic fields (EMF) exposure on human health. To date several studies have been published concerning the effects of acute MP exposure on psychomotor performances. This study investigated the effects of daily exposure to GSM 900 type MP on cognitive

function. Fifty-five subjects (27 male and 28 female) were divided into two groups: a group with MP switched on and a group with MP switched off. The two groups were matched according to age, gender, and IQ. This double blind study lasted for 45 days and was divided in three periods: baseline (BLP, 2 days), exposure (EP, 27 days), and recovery (RP, 13 days). Subjects were exposed during EP and sham exposed during RP for 2 h/day, 5 days/week. The neuropsychological test battery composed of 22 tasks screened four neuropsychological categories: information processing, attention capacity, memory function, and executive function. This neuropsychological battery was performed four times on day 2 (BLP), day 15 (EP), day 29 (EP), and day 43 (RP). Our results indicate that daily MP use has no effect on cognitive function after a 13-h rest period.

Bisht KS, Moros EG, Straube WL, Baty JD, Roti Roti JL, The Effect of 835.62 MHz FDMA or 847.74 MHz CDMA Modulated Radiofrequency Radiation on the Induction of Micronuclei in C3H 10T $\frac{1}{2}$ Cells. *Radiat. Res.* 157, 506–515, 2002.

To determine if radiofrequency (RF) radiation induces the formation of micronuclei, C3H 10T $\frac{1}{2}$ cells were exposed to 835.62 MHz frequency division multiple access (FDMA) or 847.74 MHz code division multiple access (CDMA) modulated RF radiation. After the exposure to RF radiation, the micronucleus assay was performed by the cytokinesis block method using cytochalasin B treatment. The micronuclei appearing after mitosis were scored in binucleated cells using acridine orange staining. The frequency of micronuclei was scored both as the percentage of binucleated cells with micronuclei and as the number of micronuclei per 100 binucleated cells. Treatment of cells with cytochalasin B at a concentration of 2 μ g/ml for 22 h was found to yield the maximum number of binucleated cells in C3H 10T $\frac{1}{2}$ cells. The method used for the micronucleus assay in the present study detected a highly significant dose response for both indices of micronucleus production in the dose range of 0.1–1.2 Gy and it was sensitive enough to detect a significant ($P > 0.05$) increase in micronuclei after doses of 0.3 Gy in exponentially growing cells and after 0.9 Gy in plateau-phase cells. Exponentially growing cells or plateau-phase cells were exposed to CDMA (3.2 or 4.8 W/kg) or FDMA (3.2 or 5.1 W/kg) RF radiation for 3, 8, 16 or 24 h. In three repeat experiments, no exposure condition was found by analysis of variance to result in a significant increase relative to sham-exposed cells either in the percentage of binucleated cells with micronuclei or in the number of micronuclei per 100 binucleated cells. In this study, data from cells exposed to different RF signals at two SARs were compared to a common sham-exposed sample. We used the Dunnett's test, which is specifically designed for this purpose, and found no significant exposure-related differences for either plateau-phase cells or exponentially growing cells. Thus the results of this study are not consistent with the possibility that these RF radiations induce micronuclei.

Blettner M, Schlehofer B, Breckenkamp J, Kowall B, Schmiedel S, Reis U, Potthoff P, Schuez J, Berg-Beckhoff G. Mobile phone base stations and adverse health effects: Phase 1: A population-based cross-sectional study in Germany. *Occup Environ Med.* 66:118-123, 2009.

Abstract **OBJECTIVE:** The aim of this first phase of a cross-sectional study from Germany was to investigate whether proximity of residence to mobile phone base stations as well as risk perception is associated with health complaints. **METHODS:** We conducted a population-based multi-phase cross-sectional study within the context of a large panel survey regularly carried out by a private research institute in Germany. In the initial phase, which we will report on in this paper, 30,047 persons from a total of 51,444 who took part in the nationwide survey also answered questions on how mobile phone base stations affect their health. A list of 38 health complaints was used. A multiple linear regression model was used to identify predictors of health complaints including proximity of residence to mobile phone base stations and risk perception. **RESULTS:** Of the 30,047 participants (response rate 58.6%), 18.7% of participants were concerned about adverse health effects of mobile phone base stations, while an additional 10.3% attributed their personal adverse health effects to the exposure from them. Participants who are concerned about or attribute adverse health effects to mobile phone base stations and those living in the vicinity of a mobile phone base station (500 m) reported slightly more health complaints than others. **CONCLUSIONS:** A substantial proportion of the German population is concerned about adverse health effects caused by exposure from mobile phone base stations. The observed slightly higher prevalence of health complaints near base stations can however not be fully explained by attributions or concerns.

Bolshakov MA, Alekseev SI, Bursting responses of Lymnea neurons to microwave radiation. *Bioelectromagnetics* 13(2):119-129, 1992.

Microelectrode and voltage-clamp techniques were modified to record spontaneous electrical activity and ionic currents of *Lymnea stagnalis* neurons during exposure to a 900-MHz field in a waveguide-based apparatus. The field was pulse-modulated at repetition rates ranging from 0.5 to 110 pps, or it was applied as a continuous wave (CW). When subjected to pulsed waves (PW), rapid, burst-like changes in the firing rate of neurons occurred at SARs of a few W/kg. If the burst-like irregularity was present in the firing rate under control conditions, irradiation enhanced its probability of occurrence. The effect was dependent on modulation, but not on modulation frequency, and it had a threshold SAR near 0.5 W/kg. CW radiation had no effect on the firing rate pattern at the same SAR. Mediator-induced, current activation of acetylcholine, dopamine, serotonin, or gamma-aminobutyric-acid receptors of the neuronal soma was not altered during CW or PW exposures and, hence, could not have been responsible for the bursting effect.

Borbely, AA, Huber, R, Graf, T, Fuchs, B, Gallmann, E, Achermann, P, Pulsed high-frequency electromagnetic field affects human sleep and sleep electroencephalogram. *Neurosci Lett* 275(3):207-210, 1999.

To investigate whether the electromagnetic field (EMF) emitted by digital radiotelephone handsets affects the brain, healthy, young subjects were exposed during an entire night-time sleep episode to an intermittent radiation schedule (900 MHz; maximum specific absorption rate 1 W/kg) consisting of alternating 15-min on-15-min off intervals. Compared with a control night with sham exposure, the amount of waking after sleep onset was reduced from 18 to 12 min. Spectral power of the electroencephalogram in non-rapid eye movement sleep was increased. The maximum rise occurred in the 10-11 Hz and 13.5-14 Hz bands during the initial part of sleep and then subsided. The results demonstrate that pulsed high-frequency EMF in the range of radiotelephones may promote sleep and modify the sleep EEG.

Bornhausen M, Scheingraber H, Prenatal exposure to 900 MHz, cell-phone electromagnetic fields had no effect on operant-behavior performances of adult rats. *Bioelectromagnetics* 21(8):566-574, 2000.

To clarify potential health risks of radio-frequency electromagnetic fields (EMFs) used in cellular telephone technology to the developing brain, Wistar rats were continuously exposed during pregnancy to a low-level (0.1 mW/cm²) 900 MHz, 217 Hz pulse modulated EMF that approximated the highest legal exposure of normal populations to the radiation of base antennas of the GSM digital cell-phone technology. Whole body average specific absorption rate (SAR) values for the freely roaming, pregnant animals were measured in models; they ranged between 17.5 and 75 mW/kg. The offspring of exposed and of sham-exposed dams were coded and tested later as adults in a battery of ten simultaneously operated test chambers (Skinner boxes) during night time. Eight groups of ten coded animals in each group were tested for learning deficits in a sequence of nine, computer-controlled, 15 h sessions of the food-reinforced contingency Differential Reinforcement of Rate with increasing performance requirements. Two different sets of events were recorded: The food-reinforced lever-pressing activity of the animals and the inter-response intervals (IRIs) between consecutive lever presses. IRI-occurrence patterns discriminated consistently between "learners" and "non-learners". Analyses of performance scores and of IRI-patterns both showed that exposure in-utero to the GSM field did not induce any measurable cognitive deficits.

Bortkiewicz A, Pilacik B, Gadzicka E, Szymczak W. The excretion of 6-hydroxymelatonin sulfate in healthy young men exposed to electromagnetic fields emitted by cellular phone -- an experimental study. *Neuroendocrinol Lett* 23 Suppl 1:88-91, 2002.

OBJECTIVES: It is quite likely that non-visible electromagnetic fields (EMF) may affect melatonin production. Some studies confirmed this hypothesis and showed that extremely low EMF altered pineal function in animals and humans. Thus, it is reasonable to suppose that EMF emitted by cellular phones may also influence secretion of melatonin. The present study sought to evaluate possible effect of the exposure to EMF emitted by cellular phone on 6-hydroxymelatonin sulfate (6-OHMS) excretion, which reflects melatonin levels in blood. **MATERIAL AND METHODS:** The examined group consisted of 9 healthy males aged 19-29 years. The experiment was performed under controlled conditions (the light intensity-50 lx till midnight and 0 lx during night). Each person was examined twice: on a day without exposure (control day, C-day) and on a day with continuous exposure (60 min. exposure from cellular phone, frequency 900 MHz, pulsed with 217 Hz, pulse with 576 micros, SAR 1.23 W/kg, E-day). From 7 p.m. to 8 p.m. they used a cellular phone. The subjects did not know which day was E-day, and which was C-day. From 8 p.m. till midnight the subjects listened to

music and than they slept till 7 a.m. next day. Urine samples were collected at 7 p.m., at midnight, and at 7 a.m. in the same way in C-day as in E-day. Sample were frozen for later ELISA analysis of 6-OHMS. The 6-OHMS ELISA kit from Immuno-Biological Laboratories (Hamburg) was used for measurement of 6-OHMS. The data were analysed using Wilcoxon matched-pairs signed-ranks test for each subject and for the whole group. We compared 6-OHMS level on the E-day and on the C-day separately for 3 time-points - 7 p.m., midnight, 7 a.m. RESULTS: Mean 6-OHMS level in both experiments did not differ significantly for any of the respective time points. Circadian variations of 6-OHMS level were detected in all subjects. CONCLUSIONS: The results of our investigation has demonstrated that EMF emitted by cellular phones has no distinct influence on the melatonin level.

Braune, S, Wrocklage, C, Raczek, J, Gailus, T, Lucking, CH, Resting blood pressure increase during exposure to a radio-frequency electromagnetic field. *Lancet* 351(9119):1857-1858, 1998.

Exposure of the right hemisphere to a radiofrequency EMF for 35 min causes in human subjects an increase in sympathetic efferent activity with increases the resting blood pressure between 5-10 mm Hg. The effect is likely caused by vasoconstriction.

Braune S, Riedel A, Schulte-Monting J, Raczek J. Influence of a radiofrequency electromagnetic field on cardiovascular and hormonal parameters of the autonomic nervous system in healthy individuals. *Radiat Res* 158(3):352-356, 2002.

The potential health risks of radiofrequency electromagnetic fields (EMFs) emitted by mobile phones are of considerable public interest. The present study investigated the hypothesis, based on the results of our previous study, that exposure to EMFs can increase sympathetic vasoconstrictor activity. Forty healthy young males and females underwent a single-blind, placebo-controlled protocol once on each of two different days. Each investigation included successive periods of placebo and EMF exposure, given in a randomized order. The exposure was implemented by a GSM-like signal (900 MHz, pulsed with 217 Hz, 2 W) using a mobile phone mounted on the right-hand side of the head in a typical telephoning position. Each period of placebo exposure and of EMF exposure consisted of 20 min of supine rest, 10 min of 70 degrees upright tilt on a tilt table, and another 20 min of supine rest. Blood pressure, heart rate and cutaneous capillary perfusion were measured continuously. In addition, serum levels of norepinephrine, epinephrine, cortisol and endothelin were analyzed in venous blood samples taken every 10 min. Similar to the previous study, systolic and diastolic blood pressure each showed slow, continuous, statistically significant increases of about 5 mmHg during the course of the protocol. All other parameters either decreased in parallel or remained constant. However, analysis of variance showed that the changes in blood pressure and in all other parameters were independent of the EMF exposure. These findings do not support the assumption of a nonthermal influence of EMFs emitted by mobile phones on the cardiovascular autonomic nervous system in healthy humans.

Brillaud E, Piotrowski A, de Seze R. Effect of an acute 900MHz GSM exposure on glia in the rat brain: A time-dependent study. *Toxicology*. 2007 May 26; [Epub ahead of print]

Because of the increasing use of mobile phones, the possible risks of radio frequency electromagnetic fields adverse effects on the human brain has to be evaluated. In this work we measured GFAP expression, to evaluate glial evolution 2, 3, 6 and 10 days after a single GSM exposure (15min, brain averaged SAR=6W/kg, 900MHz signal) in the rat brain. A statistically significant increase of GFAP stained surface area was observed 2 days after exposure in the frontal cortex and the caudate putamen. A smaller statistically significant increase was noted 3 days after exposure in the same areas and in the cerebellum cortex. Our results confirm the Mausset-Bonnefont et al. study [Mausset-Bonnefont, A.L., Hirbec, H., Bonnefont, X., Privat, A., Vignon, J., de Seze, R., 2004. Acute exposure to GSM 900MHz electromagnetic fields induces glial reactivity and biochemical modifications in the rat brain. *Neurobiol. Dis.* 17, 445-454], showing the existence of glial reactivity after a 15min GSM acute exposure at a brain averaged SAR of 6W/kg. We conclude to a temporary effect, probably due to a hypertrophy of glial cells, with a temporal and a spatial modulation of the effect. Whether this effect could be harmful remains to be studied.

Burch JB, Reif JS, Noonan CW, Ichinose T, Bachand AM, Koleber TL, Yost MG. Melatonin metabolite excretion among cellular telephone users. *Int J Rad Biol* 78: 1029-1036, 2002.

Abstract: *Purpose:* The relationship between cellular telephone use and excretion of the melatonin metabolite 6-hydroxymelatonin sulfate (6-OHMS) was evaluated in two populations of male electric utility workers (Study 1, $n=149$; Study 2, $n=77$).

Materials and methods: Participants collected urine samples and recorded cellular telephone use over 3 consecutive workdays. Personal 60-Hz magnetic field (MF) and ambient light exposures were characterized on the same days using EMDEX II meters. A repeated measures analysis was used to assess the effects of cellular telephone use, alone and combined with MF exposures, after adjustment for age, participation month and light exposure.

Results: No change in 6-OHMS excretion was observed among those with daily cellular telephone use >25 min in Study 1 (5 worker-days). Study 2 workers with >25 min cellular telephone use per day (13 worker-days) had lower creatinine-adjusted mean nocturnal 6-OHMS concentrations ($p=0.05$) and overnight 6-OHMS excretion ($p=0.03$) compared with those without cellular telephone use. There was also a linear trend of decreasing mean nocturnal 6-OHMS/creatinine concentrations ($p=0.02$) and overnight 6-OHMS excretion ($p=0.08$) across categories of increasing cellular telephone use. A combined effect of cellular telephone use and occupational 60-Hz MF exposure in reducing 6-OHMS excretion was also observed in Study 2.

Conclusions: Exposure-related reductions in 6-OHMS excretion were observed in Study 2, where daily cellular telephone use of >25 min was more prevalent. Prolonged use of cellular telephones may lead to reduced melatonin production, and elevated 60-Hz MF exposures may potentiate the effect.

Cain CD, Thomas DL, Adey WR, Focus formation of C3H/10T1/2 cells and exposure to a 836.55 MHz modulated radiofrequency field. *Bioelectromagnetics* 18(3):237-243, 1997.

Disruption of communication between transformed cells and normal cells is involved in tumor promotion. We have tested the hypothesis that exposures to radiofrequency (RF) fields using a form of digital modulation (TDMA) and a chemical tumor promoter, 12-O-tetradecanoylphorbol-13-acetate (TPA), are copromoters that enhance focus formation of transformed cells in coculture with parental C3H/10T1/2 murine fibroblasts. RF field exposures did not influence TPA's dose-dependent promotion of focus formation in coculture. Cell cultures were exposed to an 836.55 MHz TDMA-modulated field in TEM transmission line chambers, with incident energies that simulated field intensities at a user's head. Specific absorption rates (SARs) of 0.15, 1.5, and 15 $\mu\text{W/g}$ were used during each digital packet, and the packet frequency was 50/s. The TEM chambers were placed in a commercial incubator at 37 degrees C and 95% humidity/5% CO₂. The RF field exposures were in a repeating cycle, 20 min on, 20 min off, 24 h/day for 28 days. At 1.5 $\mu\text{W/g}$, TPA-induced focus formation (at 10, 30, and 50 ng/ml) was not significantly different in RF-exposed cultures compared to parallel sham-exposed cultures in ten independent experiments in terms of the number, density, and area of foci. Similarly, at 0.15 and 15.0 $\mu\text{W/g}$, in two and four experiments, respectively, RF exposure did not alter TPA-induced focus formation. The findings support a conclusion that repeated exposures to this RF field do not influence tumor promotion in vitro, based on the RF field's inability to enhance TPA-induced focus formation.

Cao Z, Liu J, Li S, Zhao X. [Effects of electromagnetic radiation from handsets of cellular telephone on neurobehavioral function] *Wei Sheng Yan Jiu* 29(2):102-103, 2000.

[Article in Chinese]

In order to study the effects of electromagnetic radiation from handsets of cellular telephone on neurobehavioral function, 81 staff with handsets of cellular telephone and 63 staff without handsets of cellular telephone from corporations were selected as the subjects. The subjects were investigated by questionnaire on their general health, lifestyle habit, suppress of spirit, handset using of cellular telephone, environmental exposure, morbidity, and the neurobehavioral core test battery (NCTB). The data was analyzed by chi-square, stepwise regression analysis and covariance statistics. The results showed that the average reaction time in user's group was longer than that in control group ($P < 0.01$). The time of using handset was negatively associated with corrected reaction number ($P < 0.01$). The fast reaction time and the slowest reaction time were positively associated with the length of handset using ($P < 0.01$, $P < 0.05$). The results suggested that the handset using could cause adverse health effects in neurobehavioral function.

Capri M, Scarcella E, Fumelli C, Bianchi E, Salvioli S, Mesirca P, Agostini C, Antolini A, Schiavoni A, Castellani

G, Bersani F, Franceschi C. In vitro exposure of human lymphocytes to 900 MHz CW and GSM modulated radiofrequency: studies of proliferation, apoptosis and mitochondrial membrane potential. *Radiat Res.* 162(2):211-218, 2004a .

The aim of this study was to investigate the nonthermal effects of radiofrequency (RF) fields on human immune cells exposed to a Global System for Mobile Communication (GSM) signal generated by a commercial cellular phone and by a sinusoidal non-modulated signal. To assess whether mobile phone RF-field exposure affects human immune cell functions, peripheral blood mononuclear cells (PBMCs) from healthy donors were exposed in vitro to a 900 MHz GSM or continuous-wave (CW) RF field 1 h/day for 3 days in a transverse electromagnetic mode (TEM) cell system (70-76 mW/kg average specific absorption rate, SAR). The cells were cultured for 48 or 72 h, and the following end points were studied: (1) mitogen-induced proliferation; (2) cell cycle progression; (3) spontaneous and 2-deoxy-D-ribose (dRib)-induced apoptosis; (4) mitochondrial membrane potential modifications during spontaneous and dRib-induced-apoptosis. Data obtained from cells exposed to a GSM-modulated RF field showed a slight decrease in cell proliferation when PBMCs were stimulated with the lowest mitogen concentration and a slight increase in the number of cells with altered distribution of phosphatidylserine across the membrane. On the other hand, cell cycle phases, mitochondrial membrane potential and susceptibility to apoptosis were found to be unaffected by the RF field. When cells were exposed to a CW RF field, no significant modifications were observed in comparison with sham-exposed cells for all the end points investigated.

Capri M, Scarcella E, Bianchi E, Fumelli C, Mesirca P, Agostini C, Remondini D, Schuderer J, Kuster N, Franceschi C, Bersani F. 1800 MHz radiofrequency (mobile phones, different Global System for Mobile communication modulations) does not affect apoptosis and heat shock protein 70 level in peripheral blood mononuclear cells from young and old donors. *Int J Radiat Biol.* 80(6):389-397, 2004b.

PURPOSE: To study if prolonged in vitro exposure to 1800MHz radiofrequency (RF) could exert an effect on human peripheral blood mononuclear cells (PBMC) from young and elderly donors by affecting apoptosis, mitochondrial membrane potential and heat shock protein (HSP) 70 levels. **MATERIALS AND METHODS:** Endpoints were analysed in the presence or absence of the apoptosis-inducing agent 2-deoxy-D-ribose. Three different signal modulations typical of the Global System for Mobile communication (GSM) system were applied. The modulations are widely used in mobile telephony (GSM Basic, discontinuous transmission [DTX] and Talk) at specific absorption rates of 1.4 and 2.0 W kg⁻¹. **RESULTS:** In all conditions and for all endpoints tested, there was no significant difference between RF- and sham-exposed cells. **CONCLUSION:** 1800MHz RF could not induce apoptosis by itself or affect the apoptotic phenomenon when induced by an apoptotic agent. Moreover, RF did not modify the mitochondrial functionality and the expression of HSP 70.

[Capri M](#), [Salvioli S](#), [Altilia S](#), [Sevini F](#), [Remondini D](#), [Mesirca P](#), [Bersani F](#), [Monti D](#), [Franceschi C](#) Age-Dependent Effects of in Vitro Radiofrequency Exposure (Mobile Phone) on CD95+ T Helper Human Lymphocytes. *Ann N Y Acad Sci.* 1067:493-499, 2006.

.Recent studies on "nonthermal" effects of mobile phone radiofrequency (RF) suggest that RF can interact with cellular functions and molecular pathways. To study the possible RF effects on human lymphocyte activation, we analyzed CD25, CD95, CD28 molecules in unstimulated and stimulated CD4+ e CD8+ T cells in vitro. Peripheral blood mononuclear cells (PBMCs) from young and elderly donors were exposed or sham-exposed to RF (1,800 MHz, Specific Absorption Rate 2 W/kg) with or without mitogenic stimulation. No significant changes in the percentage of these cell subsets were found between exposed and sham-exposed lymphocytes in both young and elderly donors. Nevertheless, after RF exposure we observed a slight, but significant, downregulation of CD95 expression in stimulated CD4+ T lymphocytes from elderly, but not from young donors. This age-related result is noteworthy given the importance of such a molecule in regulation of the immune response.

[Caraglia M](#), [Marra M](#), [Mancinelli F](#), [D'Ambrosio G](#), [Massa R](#), [Giordano A](#), [Budillon A](#), [Abbruzzese A](#), [Bismuto E](#). Electromagnetic fields at mobile phone frequency induce apoptosis and inactivation of the multi-chaperone complex in human epidermoid cancer cells. *J Cell Physiol.* 204(2):539-548, 2005.

The exposure to non-thermal microwave electromagnetic field (MW-EMF) at 1.95 MHz, a frequency used in mobile communication, affects the refolding kinetics of eukaryotic proteins (Mancinelli et al., 2004). On these basis we have evaluated the in vivo effect of MW-EMF in human epidermoid cancer KB cells. We have found that MW-EMF induces time-dependent apoptosis (45% after 3 h) that is paralleled by an about 2.5-fold decrease of the expression of ras and Raf-1 and of the activity of ras and Erk-1/2. Although also the expression of Akt was reduced its activity was unchanged likely as a consequence of the increased expression of its upstream activator PI3K. In the same experimental conditions an about 2.5-fold increase of the ubiquitination of ras and Raf-1 was also found and the addition for 12 h of proteasome inhibitor lactacystin at 10 microM caused an accumulation of the ubiquitinated isoforms of ras and Raf-1 and counteracted the effects of MW-EMF on ras and Raf-1 expression suggesting an increased proteasome-dependent degradation induced by MW-EMF. The exposure of KB cells to MW-EMF induced a differential activation of stress-dependent pathway with an increase of JNK-1 activity and HSP70 and 27 expression and with a reduction of p38 kinase activity and HSP90 expression. The overexpression of HSP90 induced by transfection of KB cells with a plasmid encoding for the factor completely antagonized the apoptosis and the inactivation of the ras --> Erk-dependent survival signal induced by MW-EMF. Conversely, the inhibition of Erk activity induced by 12 h exposure to 10 mM Mek-1 inhibitor U0126 antagonized the effects induced by HSP90 transfection on apoptosis caused by MW-EMF. In conclusion, these results demonstrate for the first time that MW-EMF induces apoptosis through the inactivation of the ras --> Erk survival signaling due to enhanced degradation of ras and Raf-1 determined by decreased expression of HSP90 and the consequent increase of proteasome dependent degradation.

Cardis E, Deltour I, Mann S, Moissonnier M, Taki M, Varsier N, Wake K, Wiart J. Distribution of RF energy emitted by mobile phones in anatomical structures of the brain. *Phys Med Biol.* 53(11):2771-2783, 2008.

The rapid worldwide increase in mobile phone use in the last decade has generated considerable interest in possible carcinogenic effects of radio frequency (RF). Because exposure to RF from phones is localized, if a risk exists it is likely to be greatest for tumours in regions with greatest energy absorption. The objective of the current paper was to characterize the spatial distribution of RF energy in the brain, using results of measurements made in two laboratories on 110 phones used in Europe or Japan. Most (97-99% depending on frequency) appears to be absorbed in the brain hemisphere on the side where the phone is used, mainly (50-60%) in the temporal lobe. The average relative SAR is highest in the temporal lobe (6-15%, depending on frequency, of the spatial peak SAR in the most exposed region of the brain) and the cerebellum (2-10%) and decreases very rapidly with increasing depth, particularly at higher frequencies. The SAR distribution appears to be fairly similar across phone models, between older and newer phones and between phones with different antenna types and positions. Analyses of risk by location of tumour are therefore important for the interpretation of results of studies of brain tumours in relation to mobile phone use.

Celik O, Hascalik S. Effect of electromagnetic field emitted by cellular phones on fetal heart rate patterns. *Eur J Obstet Gynecol Reprod Biol.* 112(1):55-56, 2004.

The study was planned to determine the effects of electromagnetic fields produced by cellular phones on baseline fetal heart rate, acceleration and deceleration. Forty pregnant women undergoing non-stress test were admitted to the study. Non-stress test was obtained while the subjects were holding the CP on stand by mode and on dialing mode, each for 5 min. Similar recordings were taken while there were no phones around for 10 min. Electromagnetic fields produced by cellular phones do not cause any demonstrable affect in fetal heart rate, acceleration and deceleration.

Chagnaud JL, Veyret B In vivo exposure of rats to GSM-modulated microwaves: flow cytometry analysis of lymphocyte subpopulations and of mitogen stimulation. *Int J Radiat Biol* 75(1):111-113, 1999.

The effects of GSM-modulated microwaves on lymphocyte sub-populations of Sprague-Dawley rats and their normal mitogenic responses were investigated using flow cytometry analysis and a colorimetric method. No alterations were found in the surface phenotype of splenic lymphocytes or in their mitogenic activity, indicating that low-level pulsed microwaves do not seem to affect the integrity of the immune system.

Chagnaud, JL, Moreau, JM, Veyret, B, No effect of short-term exposure to GSM-modulated low-power microwaves on benzo(a)pyrene-induced tumours in rat. *Int J Radiat Biol* 75(10):1251-1256, 1999.

PURPOSE: In view of current interest in the biological effects of amplitude-modulated microwaves arising from the rapid development of mobile communications, the effects of low-level microwaves on cancer development were investigated using a rat sarcoma model. **MATERIALS AND METHODS:** Two-month-old female Sprague-Dawley rats were treated by injection of benzo(a)pyrene and irradiated with GSM (Global System for Mobile)-modulated 900-MHz microwaves in an anechoic chamber at 55 or 200 $\mu\text{W cm}^{-2}$ (75 and 270 mW kg^{-1}) average whole-body SAR, 2h daily for 2 weeks). Rats were exposed from day 20, 40 or 75 after carcinogen injection. Additional groups of rats were sham-exposed in a second anechoic chamber. Anti-phosphatidylinositol autoantibody levels were evaluated in sera to monitor malignant transformation. **RESULTS:** Microwave exposure had no effect on the development of tumours. No acceleration or delays in tumour onset were observed. Animal survival was not modified and serum autoantibody levels were similar in exposed and sham-exposed groups. **CONCLUSION:** Low-level GSM microwave exposure of rat bearing benzo(a)pyrene-induced tumours had no effect on auto-antibody levels, tumour appearance and survival. The low exposure levels used here correspond to exposure limits for whole-body exposure of humans.

Chang SK, Choi JS, Gil HW, Yang JO, Lee EY, Jeon YS, Lee ZW, Lee M, Hong MY, Ho Son T, Hong SY. Genotoxicity evaluation of electromagnetic fields generated by 835-MHz mobile phone frequency band. *Eur J Cancer Prev.* 14(2):175-179, 2005.

It is still unclear whether the exposure to electromagnetic fields (EMFs) generated by mobile phone radiation is directly linked to cancer. We examined the biological effects of an EMF at 835 MHz, the most widely used communication frequency band in Korean CDMA mobile phone networks, on bacterial reverse mutation (Ames assay) and DNA stability (in vitro DNA degradation). In the Ames assay, tester strains alone or combined with positive mutagen were applied in an artificial mobile phone frequency EMF generator with continuous waveform at a specific absorption rate (SAR) of 4 W/kg for 48 h. In the presence of the 835-MHz EMF radiation, incubation with positive mutagen 4-nitroquinoline-1-oxide and cumene hydroxide further increased the mutation rate in *Escherichia coli* WP2 and TA102, respectively, while the contrary results in *Salmonella typhimurium* TA98 and TA1535 treated with 4-nitroquinoline-1-oxide and sodium azide, respectively, were shown as antimutagenic. However, these mutagenic or co-mutagenic effects of 835-MHz radiation were not significantly repeated in other relevant strains with same mutation type. In the DNA degradation test, the exposure to 835-MHz EMF did not change the rate of degradation observed using plasmid pBluescript SK(+) as an indicator. Thus, we suggest that 835-MHz EMF under the conditions of our study neither affected the reverse mutation frequency nor accelerated DNA degradation in vitro.

Chauhan V, Mariampillai A, Bellier PV, Qutob SS, Gajda GB, Lemay E, Thansandote A, McNamee JP. Gene Expression Analysis of a Human Lymphoblastoma Cell Line Exposed In Vitro to an Intermittent 1.9 GHz Pulse-Modulated Radiofrequency Field. *Radiat Res.* 165(4):424-429, 2006a.

This study was designed to determine whether radiofrequency (RF) fields of the type used for wireless communications could elicit a cellular stress response. As general indicators of a cellular stress response, we monitored changes in proto-oncogene and heat-shock protein expression. Exponentially growing human lymphoblastoma cells (TK6) were exposed to 1.9 GHz pulse-modulated RF fields at average specific absorption rates (SARs) of 1 and 10 W/kg. Perturbations in the expression levels of the proto-oncogenes FOS, JUN and MYC after exposure to sham and RF fields were assessed by real-time RT-PCR. In addition, the transcript levels of the cellular stress proteins HSP27 and inducible HSP70 were also monitored. We demonstrated that transcript levels of these genes in RF-field-exposed cells showed no significant difference in relation to the sham treatment group. However, concurrent positive (heat-shock) control samples displayed a significant elevation in the expression of HSP27, HSP70, FOS and JUN. Conversely, the levels of MYC mRNA were found to decline in the positive (heat-shock) control. In conclusion, our study found no evidence that the 1.9 GHz RF-field exposure caused a general stress response in TK6 cells under our experimental conditions.

Chauhan V, Mariampillai A, Gajda GB, Thansandote A, McNamee JP. Analysis of proto-oncogene and heat-shock protein gene expression in human derived cell-lines exposed in vitro to an intermittent 1.9 GHz pulse-modulated radiofrequency field. *Int J Radiat Biol.* 82(5):347-354, 2006b.

Propose: Several studies have reported that radiofrequency (RF) fields, as emitted by mobile phones, may cause changes in gene expression in cultured human cell-lines. The current study was undertaken to evaluate this possibility in two human-derived immune cell-lines. Materials and methods: HL-60 and Mono-Mac-6 (MM6) cells were individually exposed to intermittent (5 min on, 10 min off) 1.9 GHz pulse-modulated RF fields at a average specific absorption rate (SAR) of 1 and 10 W/kg at 37 +/- 0.5 degrees C for 6 h. Concurrent negative and positive (heat-shock for 1 h at 43 degrees C) controls were conducted with each experiment. Immediately following RF field exposure (T = 6 h) and 18 h post-exposure (T = 24 h), cell pellets were collected from each of the culture dishes and analyzed for transcript levels of proto-oncogenes (c-jun, c-myc and c-fos) and the stress-related genes (heat shock proteins (HSP) HSP27 and HSP70B) by quantitative reverse transcriptase polymerase chain reaction (RT-PCR). Results: No significant effects were observed in mRNA expression of HSP27, HSP70, c-jun, c-myc or c-fos between the sham and RF-exposed groups, in either of the two cell-lines. However, the positive (heat-shock) control group displayed a significant elevation in the expression of HSP27, HSP70, c-fos and c-jun in both cell-lines at T = 6 and 24 h, relative to the sham and negative control groups. Conclusion: This study found no evidence that exposure of cells to non-thermalizing levels of 1.9 GHz pulse-modulated RF fields can cause any detectable change in stress-related gene expression.

Chen ZJ, He JL. [Mutagenic, carcinogenic and teratogenic effects induced by radiofrequency electromagnetic field of mobile phone.] Zhejiang Da Xue Xue Bao Yi Xue Ban. 37(1):97-102, 2008.

[Article in Chinese]

OBJECTIVE: The extensive use of mobile phones causes increasing public concern on health effects of exposure to radiofrequency (RF) electromagnetic fields. Conflicting results are found in publications on the mutagenic, carcinogenic and teratogenic effects of RF electromagnetic fields. The overwhelming findings do not support the assumption that RF exposure may induce mutagenic, carcinogenic or teratogenic effects. However, health effects from low level RF exposure need to be further studied.

Chia SE, Chia HP, Tan JS, Prevalence of headache among handheld cellular telephone users in singapore: A community study. *Environ Health Perspect* 108(11):1059-1062, 2000.

We carried out a cross-sectional community study in Singapore to determine the prevalence of specific central nervous system (CNS) symptoms among hand-held cellular telephone (HP) users compared to nonusers and to study the association of risk factors and CNS symptoms among HP users. A total of 808 men and women between 12 and 70 years of age, who lived in one community, were selected using one-stage cluster random sampling and responses to a structured questionnaire. The prevalence of HP users was 44.8%. Headache was the most prevalent symptom among HP users compared to non-HP users, with an adjusted prevalence rate ratio of 1.31 [95% confidence interval, 1.00-1.70]. There is a significant increase in the prevalence of headache with increasing duration of usage (in minutes per day). Prevalence of headache was reduced by more than 20% among those who used hand-free equipment for their cellular telephones as compared to those who never use the equipment. The use of HPs is not associated with a significant increase of CNS symptoms other than headache.

Christensen HC, Schüz J, Kosteljanetz M, Poulsen HS, Thomsen J, Johansen J. Cellular Telephone Use and Risk of Acoustic Neuroma *Am J Epidemiol* 159:277-283, 2004.

Despite limited evidence, cellular telephones have been claimed to cause cancer, especially in the brain. In this Danish study, the authors examined the possible association between use of cellular telephones and development of acoustic neuroma. Between 2000 and 2002, they ascertained 106 incident cases and matched these persons with 212 randomly sampled, population-based controls on age and sex. The data obtained included information on use of cellular telephones from personal interviews, data from medical records, and the results of radiologic examinations. The authors obtained information on socioeconomic factors from Statistics Denmark. The overall estimated relative risk of acoustic neuroma was 0.90 (95% confidence interval: 0.51, 1.57). Use

of a cell phone for 10 years or more did not increase acoustic neuroma risk over that of short-term users. Furthermore, tumors did not occur more frequently on the side of the head on which the telephone was typically used, and the size of the tumor did not correlate with the pattern of cell phone use. The results of this prospective, population-based, nationwide study, which included a large number of long-term users of cellular telephones, do not support an association between cell phone use and risk of acoustic neuroma.

Christensen, HC; Schüz, J; Kosteljanetz, M; Poulsen, HS; Boice, JD. Jr; McLaughlin, JK; Johansen, C. Cellular telephones and risk for brain tumors: A population-based, incident case-control study. *Neurology* 64: 1189-1195, 2005.

Objective: To evaluate a possible association of glioma or meningioma with use of cellular telephones, using a nationwide population-based case-control study of incident cases of meningioma and glioma.

Methods: The authors ascertained all incident cases of glioma and meningioma diagnosed in Denmark between September 1, 2000, and August 31, 2002. They enrolled 252 persons with glioma and 175 persons with meningioma aged 20 to 69. The authors also enrolled 822 randomly sampled, population-based controls matched for age and sex. Information was obtained from personal interviews, medical records containing diagnoses, and the results of radiologic examinations. For a small number of cases and controls, the authors obtained the numbers of incoming and outgoing calls. They evaluated the memory of the respondents with the Mini-Mental State Examination and obtained data on socioeconomic factors from Statistics Denmark.

Results: There were no material socioeconomic differences between cases and controls or participants and non-participants. Use of cellular telephone was associated with a low risk for high-grade glioma (OR, 0.58; 95% CI, 0.37 to 0.90). The risk estimates were closer to unity for low-grade glioma (1.08; 0.58 to 2.00) and meningioma (1.00; 0.54 to 1.28).

Conclusion: The results do not support an association between use of cellular telephones and risk for glioma or meningioma.

Cinel C, Boldini A, Russo R, Fox E. Effects of mobile phone electromagnetic fields on an auditory order threshold task. *Bioelectromagnetics*. 2007 May 10; [Epub ahead of print]

The effect of acute exposure to radio frequency electromagnetic fields (RF EMF) generated by mobile phones on an auditory threshold task was investigated. 168 participants performed the task while exposed to RF EMF in one testing session (either global system for mobile communication (GSM) or unmodulated signals) while in a separate session participants were exposed to sham signals. Lateralization effects were tested by exposing participants either on the left side or on the right side of the head. No significant effect of exposure to RF EMF was detected, suggesting that acute exposure to RF EMFs does not affect performance in the order threshold task.

Cook A, Woodward A, Pearce N, Marshall C. Cellular telephone use and time trends for brain, head and neck tumours. *N Z Med J*. 116(1175):U457, 2003.

AIM: The objective of this study was to determine whether incidence rates of head and neck malignancies in New Zealand have varied since the introduction of cellular telephones in 1987. In particular, we sought to compare trends in tumour rates in anatomical sites that receive high, medium and low levels of cellular telephone radiation (based on dosimetry data). **METHODS:** We investigated whether trends in tumour incidence rates in New Zealand have varied since the introduction of cellular telephones in 1987. The exposure measure used was the proportion of cellular telephone subscribers within the national population, calculated using the number of subscribers over the study period. **RESULTS:** The graphs for high, medium and low exposure sites did not display any significant changes in trend patterns for either gender over the years 1986 to 1998. **CONCLUSIONS:** Incidence rates for malignancies arising in the head and neck, including those sites that hypothetically receive the highest levels of radio frequency radiation during cellular telephone

use, have not changed materially since the introduction of cellular telephones to New Zealand. However, ecological studies of this nature are limited in many ways and a stronger study design is clearly needed to establish more exactly any elevation in risk.

Cranfield CG, Wood AW, Anderson V, Menezes KG. Effects of mobile phone type signals on calcium levels within human leukaemic T-cells (Jurkat cells). *Int J Radiat Biol* 77(12):1207-1217, 2001.

PURPOSE: To test whether exposure to simulated GSM mobile phone signals (915 MHz, 2 W kg⁻¹) influences the concentration of calcium or calcium signalling patterns in a human lymphocyte cell line. **MATERIALS AND METHODS:** The radiofrequency (RF) energy was delivered via a coaxial applicator to a perfused chamber where cells adherent to a thin glass coverslip were imaged by laser scanning confocal microscopy. Cell calcium concentration, estimated from Fluo-3 fluorescence, was monitored over two 10-min periods; control followed by exposed/sham, with exposure status assigned in a blind and randomized fashion. Both continuous wave (CW) and pulsed wave (PW) RF (on both phytohaemagglutinin-activated and unactivated cells) were studied (with an equal number of sham exposures) on 100 cells per category (total 800 cells). **RESULTS:** No significant changes were noted for the following: regression slope of calcium fluorescence; mean calcium concentration; number of calcium 'spikes' in each 10 min; or mean height of these 'spikes'. The average frequency from Fourier spectra of these periods showed significant alteration in one category only: PW exposure of activated cells. **CONCLUSIONS:** There is no clear indication that RF emissions from mobile phones are associated with any changes in calcium levels or calcium signalling in lymphocytes.

Croft R, Chandler J, Burgess A, Barry R, Williams J, Clarke A. Acute mobile phone operation affects neural function in humans. *Clin Neurophysiol* 113(10):1623, 2002.

OBJECTIVES: Mobile phones (MP) are used extensively and yet little is known about the effects they may have on human physiology. There have been conflicting reports regarding the relation between MP use and the electroencephalogram (EEG). The present study suggests that this conflict may be due to methodological differences such as exposure durations, and tests whether exposure to an active MP affects EEG as a function of time. **METHODS:** Twenty-four subjects participated in a single-blind fully counterbalanced cross-over design, where both resting EEG and phase-locked neural responses to auditory stimuli were measured while a MP was either operating or turned off. **RESULTS:** MP exposure altered resting EEG, decreasing 1-4Hz activity (right hemisphere sites), and increasing 8-12Hz activity as a function of exposure duration (midline posterior sites). MP exposure also altered early phase-locked neural responses, attenuating the normal response decrement over time in the 4-8Hz band, decreasing the response in the 12-30Hz band globally and as a function of time, and increasing midline frontal and lateral posterior responses in the 30-45Hz band. **CONCLUSIONS:** Active MPs affect neural function in humans and do so as a function of exposure duration. The temporal nature of this effect may contribute to the lack of consistent results reported in the literature.

Croft RJ, Hamblin DL, Spong J, Wood AW, McKenzie RJ, Stough C. The effect of mobile phone electromagnetic fields on the alpha rhythm of human electroencephalogram. *Bioelectromagnetics*. 2007 Sep 4; [Epub ahead of print]

Mobile phones (MP) emit low-level electromagnetic fields that have been reported to affect neural function in humans; however, demonstrations of such effects have not been conclusive. The purpose of the present study was to test one of the strongest findings in the literature; that of increased "alpha" power in response to MP-type radiation. Healthy participants (N = 120) were tested using a double-blind counterbalanced crossover design, with each receiving a 30-min Active and a 30-min Sham Exposure 1 week apart, while electroencephalogram (EEG) data were recorded. Resting alpha power (8-12 Hz) was then derived as a function of time, for periods both during and following exposure. Non-parametric analyses were employed as data could not be normalized. Previous reports of an overall alpha power enhancement during the MP exposure were confirmed (relative to Sham), with this effect larger at ipsilateral than contralateral sites over posterior regions. No overall change to alpha power was observed following exposure cessation; however, there was less alpha power contralateral to the exposure source during this period (relative to ipsilateral). Employing a strong methodology, the current findings support previous research that has reported an effect of MP exposure on EEG alpha power.

Crouzier D, Debouzy JC, Bourbon F, Collin A, Perrin A, Testylier G. Neurophysiologic effects at low level 1.8 GHz radiofrequency field exposure: a multiparametric approach on freely moving rats. Pathol Biol (Paris). 2006 Jul 31; [Epub ahead of print]

Deleterious effects on healthcare and particularly disruption of the cholinergic system have been reported after exposure to radiofrequency field at low power density. This work presents a 72 hours multiparametric study, where cholinergic system was investigated using a neurochemical, electrophysiological and physiological approaches. Free moving rats were exposed 24 hours to RF GSM signal at 1.8 GHz at low power density (1.2 and 9 W/m(2)). Acetylcholine (ACh) release in the hippocampus was simultaneously monitored using the microdialysis technique, electroencephalogram (EEG), electromyogram (EMG) and subcutaneous temperature. A spectral analysis of EEG was also performed and sleep stages were determined. After experimental time, the animals were sacrificed and a NMR study was performed on lipid brain extract. No significant parameters modification was observed under RF exposure. The only significant difference was the lack of increase in time spent in REM sleep, the third day, for the 1.2 W/m(2) group. This observation appeared difficult to explain and could not be reasonably related with RF exposure. Similarly, the NMR study also failed to show any effect of RF.

Curcio G, Ferrara M, De Gennaro L, Cristiani R, D'Inzeo G, Bertini M. Time-course of electromagnetic field effects on human performance and tympanic temperature. *Neuroreport*. 15(1):161-164, 2004.

The study aimed to investigate the time-course of electromagnetic field (EMF)-induced effects on human cognitive and behavioral performance and on tympanic temperature. Subjects were randomly assigned to two groups, exposed to a 902.40 MHz EMF before the testing session, or to the same signal during the data collecting session. Following a double-blind paradigm, subjects were tested on four performance tasks: an acoustic simple-reaction time task, a visual search task, an arithmetic descending subtraction task and an acoustic choice-reaction time task. Moreover, tympanic temperature was collected five times during each session. Results indicated an improvement of both simple- and choice-reaction times and an increase of local temperature on the exposed region under the active exposure. There was a clear time-course of the reaction time and temperature data, indicating that performance and physiological measures need a minimum of 25 min of EMF exposure to show appreciable changes.

Curcio G, Ferrara M, Moroni F, D'Inzeo G, Bertini M, De Gennaro L.

Is the brain influenced by a phone call? An EEG study of resting wakefulness. *Neurosci Res*. 2005 Aug 12; [Epub ahead of print]

We recorded the resting electroencephalogram of 20 healthy subjects in order to investigate the effect of electromagnetic field (EMF) exposure on EEG waking activity and its temporal development. The subjects were randomly assigned to two groups and exposed, in double-blind conditions, to a typical mobile phone signal (902.40MHz, modulated at 217Hz, with an average power of 0.25W) before or during the EEG recording session. The results show that, under real exposure as compared to baseline and sham conditions, EEG spectral power was influenced in some bins of the alpha band. This effect was greater when the EMF was on during the EEG recording session than before it. The present data lend further support to the idea that pulsed high-frequency electromagnetic fields can affect normal brain functioning, also if no conclusions can be drawn about the possible health effects.

Curcio G, Valentini E, Moroni F, Ferrara M, De Gennaro L, Bertini M Psychomotor performance is not influenced by brief repeated exposures to mobile phones. Bioelectromagnetics. 2007 Dec 28 [Epub ahead of print].

The present study investigated the presence of a cumulative effect of brief and repeated exposures to a GSM mobile phone (902.40 MHz, 217 Hz modulated; peak power of 2 W; average power of 0.25 W; SAR = 0.5 W/kg) on psychomotor functions. To this end, after each of 3 15-min exposures, both an acoustic simple reaction time task (SRTT) and a sequential finger tapping task (SFTT) were administered to 24 subjects. The present study was unable to detect the cumulative effects of brief and repeated EMF exposure on human psychomotor performance, although there was a non-statistical trend to shorter reaction times. In summary, these data show an absence of effects with these particular exposure conditions; however, possible cognitive effects induced by different signal characteristics cannot be excluded.

Curcio G, Ferrara M, Limongi T, Tempesta D, Di Sante G, De Gennaro L, Quaresima V, Ferrari M. Acute mobile phones exposure affects frontal cortex hemodynamics as evidenced by functional near-infrared spectroscopy. J Cereb Blood Flow Metab. 2009 Feb 25. [Epub ahead of print]

This study aimed to evaluate by functional near-infrared spectroscopy (fNIRS), the effects induced by an acute exposure (40 mins) to a GSM (Global System for Mobile Communications) signal emitted by a mobile phone (MP) on the oxygenation of the frontal cortex. Eleven healthy volunteers underwent two sessions (Real and Sham exposure) after a crossover, randomized, double-blind paradigm. The whole procedure lasted 60 mins: 10-mins baseline (Bsl), 40-mins (Exposure), and 10-mins recovery (Post-Exp). Together with frontal hemodynamics, heart rate, objective and subjective vigilance, and self-evaluation of subjective symptoms were also assessed. The fNIRS results showed a slight influence of the GSM signal on frontal cortex, with a linear increase in [HHb] as a function of time in the Real exposure condition ($F(4,40)=2.67$; $P=0.04$). No other measure showed any GSM exposure-dependent changes. These results suggest that fNIRS is a convenient tool for safely and noninvasively investigating the cortical activation in MP exposure experimental settings. Given the short-term effects observed in this study, the results should be confirmed on a larger sample size and using a multichannel instrument that allows the investigation of a wider portion of the frontal cortex.

Czyz J, Guan K, Zeng Q, Nikolova T, Meister A, Schönborn F, Schuderer J, Kuster N, Wobus AM, High frequency electromagnetic fields (GSM signals) affect gene expression levels in tumor suppressor p53-deficient embryonic stem cells. Bioelectromagnetics 25:296-307, 2004.

Effects of electromagnetic fields (EMF) simulating exposure to the Global System for Mobile Communications (GSM) signals were studied using pluripotent embryonic stem (ES) cells in vitro. Wild-type ES cells and ES cells deficient for the tumor suppressor p53 were exposed to pulse modulated EMF at 1.71 GHz, lower end of the uplink band of GSM 1800, under standardized and controlled conditions, and transcripts of regulatory genes were analyzed during in vitro differentiation. Two dominant GSM modulation schemes (GSM-217 and GSM-Talk), which generate temporal changes between GSM-Basic (active during talking phases) and GSM-DTX (active during listening phases thus simulating a typical conversation), were applied to the cells at and below the basic safety limits for local exposures as defined for the general public by the International Commission on Nonionizing Radiation Protection (ICNIRP). GSM-217 EMF induced a significant upregulation of mRNA levels of the heat shock protein, hsp70 of p53-deficient ES cells differentiating in vitro, paralleled by a low and transient increase of c-jun, c-myc, and p21 levels in p53-deficient, but not in wild-type cells. No responses were observed in either cell type after EMF exposure to GSM-Talk applied at similar slot-averaged specific absorption rates (SAR), but at lower time-averaged SAR values. Cardiac differentiation and cell cycle characteristics were not affected in embryonic stem and embryonic carcinoma cells after exposure to GSM-217 EMF signals. Our data indicate that the genetic background determines cellular responses to GSM modulated EMF.

d'Ambrosio G, Massa R, Scarfi MR, Zeni O, Cytogenetic damage in human lymphocytes following GMSK phase modulated microwave exposure. Bioelectromagnetics 23:7-13, 2002.

The present study investigated, using in vitro experiments on human lymphocytes, whether exposure to a microwave frequency used for mobile communication, either unmodulated or in presence of phase only modulation, can cause modification of cell proliferation kinetics and/or genotoxic effects, by evaluating the cytokinesis block proliferation index and the micronucleus frequency. In the GSM 1800 mobile communication systems the field is both phase (Gaussian minimum shift keying, GMSK) and amplitude (time domain multiple access, TDMA) modulated. The present study investigated only the effects of phase modulation, and no amplitude modulation was applied. Human peripheral blood cultures were exposed to 1.748 GHz, either continuous wave (CW) or phase only modulated wave (GMSK), for 15 min. The maximum specific absorption rate (~ 5 W/kg) was higher than that occurring in the head of mobile phone users; however, no changes were found in cell proliferation kinetics after exposure to either CW or GMSK fields. As far as genotoxicity is concerned, the micronucleus frequency result was not affected by CW exposure; however, a statistically significant micronucleus effect was found following exposure to phase modulated field. These results would suggest a genotoxic power of the phase modulation per se.

Dasdag, S, Ketani, MA, Akdag, Z, Ersay, AR, Sar,i I, Demirtas ,OC, Celik, MS, Whole-body microwave exposure emitted by cellular phones and testicular function of rats. *Urol Res* 27(3):219-223, 1999.

This study investigated whether there are adverse effects due to microwave exposure emitted by cellular phones in male rats. Eighteen Wistar Albino rats were separated into three groups, a sham group and two experimental groups. The rats were confined in Plexiglas cages and cellular phones were placed 0.5 cm under the cages. In the first experimental group, cellular phones were in standby position for 2 h. In the second experimental group, phones were turned to the speech position three times each for 1 min duration over 2 h. Rats in the first and second experimental groups were exposed to microwaves emitted by phones for 2 h/day for a duration of 1 month. After the last exposure the rats were killed. Brain, eyes, ears, liver, heart, lungs, stomach, kidneys, testes, small and large intestines and skin of the rats were observed histologically. The decrease of epididymal sperm counts in the speech groups were not found to be significant ($P > 0.05$). Differences in terms of normal and abnormal sperm forms were not observed ($P > 0.05$). Histological changes were especially observed in the testes of rats of the speech groups. Seminiferous tubular diameter of rat testes in the standby and speech groups was found to be lower than the sham group ($P < 0.05$). Rectal temperatures of rats in the speech group were found to be higher than the sham and standby groups ($P < 0.05$). The rectal temperatures of rats before and after exposure were also found to be significantly higher in the speech group ($P < 0.05$). Specific absorption rate (SAR) was determined as 0.141 W/kg.

Dasdag S; Akdag MZ; Ayyıldız O, Demirtas OC, Yayla M, Sert C. Do cellular phones alter blood parameters and birth weight of rats? *Electromag. Biol. Med.* 19:107-113, 2000.

The present study aimed to investigate the effects of microwaves (MW) emitted by cellular phones (CPs) on peripheral blood parameters and birth weights of rats. Thirty-six albino rats were divided into four groups, male ($n = 6$) and female sham-exposed groups ($n = 12$) and male ($n = 6$) and female experimental groups ($n = 12$). No blood parameters differed following exposure ($p > 0.05$). The birth weight of offspring in the experimental group was significantly lower than in the sham-exposed group ($p < 0.001$). No significant differences were observed between rectal temperatures of rats in the sham and experimental groups ($p > 0.05$). The specific absorption rate (SAR) was found to be 0.155 W/kg for the experimental groups. All parameters investigated were normal in the next generation of rats ($p > 0.05$).

Dasdag S, Zulkuf Akdag M, Aksen F, Yilmaz F, Bashan M, Mutlu Dasdag M, Salih Celik M. Whole body exposure of rats to microwaves emitted from a cell phone does not affect the testes. *Bioelectromagnetics* 24(3):182-188, 2003.

The objective of this study was to investigate the effects of radiofrequency radiation emitted from cellular phones on the lipid composition, malondialdehyde concentration, p53 immune reactivity, sperm count, morphology, histological structure of testes, and on rectal temperature of rats exposed to microwave radiation emitted from cellular phones. Sixteen Sprague-Dawley rats were separated into two groups of eight, sham exposed (control) and experimental. The rats were confined in plexiglas cages specially designed for this study, and cellular phones were placed 0.5 cm under the cages. For the experimental group, cellular phones were activated 20 min per day (7 days a week) for 1 month. For the control group, the cellular phones were placed beneath the cages for 20 min a day, but the phones were turned off. Rectal temperatures were measured weekly. For 250 mW radiated power, the whole body average SAR (rms) is 0.52 W/kg and 1 g averaged peak SAR (rms) is 3.13 W/kg. The Mann-Whitney U-test was used for statistical comparisons of groups. No statistically significant alteration in any of the endpoints was noted. This study found no evidence suggesting an adverse effect of cell phone exposure on measures of testicular function or structure.

Dasdag S, Akdag MZ, Ulukaya E, Uzunlar AK, Yegin D. Mobile phone exposure does not induce apoptosis on spermatogenesis in rats. *Arch Med Res.* 39(1):40-44, 2008

BACKGROUND: Some studies have reported that microwave radiation can have adverse effects on reproduction. Therefore, the purpose of this study was to investigate the apoptosis-inducing effect of mobile phone exposure on spermatogonia in seminiferous tubules. **METHODS:** The study was carried out on 31 Wistar albino adult male rats. The rats were separated into three groups in this study (cage control: 10, sham group: 7, and exposed group: 14). For the study group, rats were exposed to radiation 2 h/day (7 days/week) for 10 months. For the sham group, rats were placed into the carousel and the same procedure was applied except that the generator was turned off. For the cage control, nothing was applied to the rats in this group and they completed their life cycle in the cage during the study period. In this study, rats

were sacrificed after 10 months of exposure and their testes were taken. Testes tissue was immunohistochemically stained for the active (cleaved) caspase-3. Positively stained cells were counted in up to ten different areas, and the frequency of positive cells was determined in percentage. Scoring was done by taking into account both the intensity of staining and the distribution of positively stained cells. Therefore, protein expression was evaluated by a semiquantitative scoring system. RESULTS: The final score for apoptosis of testes in the exposed group was not statistically significant according to the sham and the cage control groups ($p > 0.05$). CONCLUSIONS: The results of this study showed that 2 h/day (7 days/week) exposure of 900 MHz radiation over a period of 10 months does not affect the active (cleaved) caspase-3 levels in testes, a well-known feature of typical apoptosis.

Davidson HC, Lutman ME. Survey of mobile phone use and their chronic effects on the hearing of a student population. *Int J Audiol*. 46(3):113-118, 2007.

[Article in English, French]

Mobile phone ownership and usage is now widespread and public concern has developed over possible harmful physiological effects of their use. This study aimed to investigate the prevalence of student mobile phone ownership and any possible chronic effects of usage on hearing, tinnitus and balance. Questionnaires for electronic self-completion were distributed to University of Southampton postgraduates, and 117 out of 160 returned met the criteria for analysis. A total of 94% were current mobile phone users, and only 2% had never used a mobile phone. Duration of ownership and daily usage ranged from 0-7 years and 0-45 minutes respectively. Text-messaging was more popular than talking. High or long-term users reported no worse hearing, tinnitus, or balance than low or short-term users. The results of this study confirm that the prevalence of mobile phone ownership amongst students is extremely high. However there appear to be no harmful effects of mobile phone usage on their audiovestibular systems within the range of exposure of the study, insofar as can be detected by the self-report method employed.

Dawe AS, Nylund R, Leszczynski D, Kuster N, Reader T, De Pomerai DI. Continuous wave and simulated GSM exposure at 1.8 W/kg and 1.8 GHz do not induce hsp16-1 heat-shock gene expression in *Caenorhabditis elegans*. *Bioelectromagnetics*. 29(2):92-99, 2008.

Recent data suggest that there might be a subtle thermal explanation for the apparent induction by radiofrequency (RF) radiation of transgene expression from a small heat-shock protein (hsp16-1) promoter in the nematode, *Caenorhabditis elegans*. The RF fields used in the *C. elegans* study were much weaker (SAR 5-40 mW kg⁻¹) than those routinely tested in many other published studies (SAR approximately 2 W kg⁻¹). To resolve this disparity, we have exposed the same transgenic hsp16-1::lacZ strain of *C. elegans* (PC72) to higher intensity RF fields (1.8 GHz; SAR approximately 1.8 W kg⁻¹). For both continuous wave (CW) and Talk-pulsed RF exposures (2.5 h at 25 degrees C), there was no indication that RF exposure could induce reporter expression above sham control levels. Thus, at much higher induced RF field strength (close to the maximum permitted exposure from a mobile telephone handset), this particular nematode heat-shock gene is not up-regulated. However, under conditions where background reporter expression was moderately elevated in the sham controls (perhaps as a result of some unknown co-stressor), we found some evidence that reporter expression may be reduced by approximately 15% following exposure to either Talk-pulsed or CW RF fields.

D'Costa H, Trueman G, Tang L, Abdel-rahman U, Abdel-rahman W, Ong K, Cosic I. Human brain wave activity during exposure to radiofrequency field emissions from mobile phones. *Australas Phys Eng Sci Med*. 26(4):162-167, 2003.

The aim of this study was to determine whether there is an effect of mobile phone electromagnetic field emissions on the human electroencephalograph (EEG). EEG recordings from ten awake subjects were taken during exposure to radiofrequency (RF) emissions from a mobile phone positioned behind the head. Two experimental trials were conducted. In the first trial, RF exposures were generated by a GSM mobile phone with the speaker disabled and configured to transmit at full-radiated power. During the second trial, exposures were generated by a non-modified GSM mobile phone in active standby mode. For each trial, subjects were exposed in five minute intervals to a randomized, interrupted

sequence of five active and five sham exposures. The experiment was conducted under single-blind conditions. The average EEG band power in active exposure recordings was compared to corresponding sham recordings. Statistical tests indicated significant difference in the full-power mode trial within the EEG alpha (8-13 Hz) and beta (13-32 Hz) bands. A subsequent statistical analysis of median spectral power in discrete EEG rhythms revealed significant differences in 7 of the 32 distinct frequencies overall. In conclusion, the results of this study lend support to EEG effects from mobile phones activated in talk-mode.

de Seze R, Ayoub J, Peray P, Miro L, Touitou Y, Evaluation in humans of the effects of radiocellular telephones on the circadian patterns of melatonin secretion, a chronobiological rhythm marker. *J Pineal Res* 27(4):237-242, 1999.

A decrease in melatonin secretion has been observed in small mammals under exposure to extremely low frequency electromagnetic fields. As there is some concern about possible health effects of the increasing use of radiocellular telephones emitting radiofrequency electromagnetic fields, we examined whether such fields would alter melatonin levels in the human. Volunteers were two groups totalling 38 men, 20-32 yr old. Exposures were to commercially available cellular telephones of the GSM 900 type (Global System for Mobile communication at 900 MHz) or DCS 1800 type (Digital Communication System at 1800 MHz), for 2 hr/day, 5 days/wk, for 4 wk, at their maximum power. Attention of the volunteers was sustained by TV projection of movies. Blood samples were collected hourly during the night and every 3 hr in the daytime. Four sampling sessions were performed at 15-day intervals: before the beginning of the exposure period, at the middle and the end of the exposure period, and 15 days later to evaluate the persistence or late appearance of potential effects. Evaluated parameters were the maximum serum concentration, the time of this maximum, and the area under the curve of the hormone profile. Melatonin circadian profile was not disrupted in 37 young male volunteers submitted to a typical pattern of exposure to the electromagnetic fields generated by two common types of cell phones.

de Seze R, Fabbro-Peray P, Miro L, GSM radiocellular telephones do not disturb the secretion of antepituitary hormones in humans. *Bioelectromagnetics* 19(5):271-278, 1998.

It is known that the endocrine system of experimental animals is susceptible to perturbation by radiofrequency (RF) radiation. Because of the recent interest in health and safety issues of cellular telephones, an experiment was designed to evaluate the effect of a 900 MHz RF radiation emitted by a Global System for Mobile radiotelephone (217 Hz impulses, one-eighth duty cycle, 2 W peak power) on human endocrine functions. Twenty healthy male volunteers aged from 19 to 40 were inducted in the present experiment. Each subject was exposed to RF radiation through the use of a cellular phone 2 h/day, 5 days/wk, for 1 month. Subjects were their own control. End points were serum adrenocorticotropin, thyrotropin, growth hormone, prolactin, luteinizing hormone, and follicle stimulating hormone concentrations. These end points were determined in nine weekly blood samples obtained starting 3 weeks before the commencement of the exposure and ending 2 weeks after exposures. All but one blood sample was drawn 48 h after each weekly session. The seventh drawing was performed the morning after the last weekly exposure. Within each individual, the preexposure hormone concentration was used as a control. Results indicated that all hormone concentrations remained within normal physiologic ranges. A difference was not noted among the nine weekly samples in five of six hormones studied. There was a significant change only in thyrotropin concentration, showing a 21% decrease on the seventh sampling. Because this change recovered fully during the postexposure period, it is concluded that 1 month of intermittent exposures to RF radiation from a cellular telephone does not induce a long-lasting or cumulative effect on the hormone secretion rate of the anterior pituitary gland in humans.

Desta AB, Owen RD, Cress LW. Non-thermal Exposure to Radiofrequency Energy from Digital Wireless Phones does not Affect Ornithine Decarboxylase Activity in L929 Cells. *Radiat Res* 160:488-491, 2003.

L929 murine fibroblast cells were exposed to radiofrequency (RF) radiation from a time division multiple access wireless phone operating at 835 MHz frequency to determine the effect of RF-radiation energy emitted by wireless phones on ornithine decarboxylase (ODC) activity in cultured cells. Exposure was for 8 h to an average specific absorption rate (SAR) from <1 W/kg up to 15 W/kg. After exposure, cells were harvested and ODC activity was measured. No statistically significant difference in ODC activity was found between RF-radiation-exposed and sham-exposed cells at

non-thermal specific absorption rates. At SARs which resulted in measurable heating of the medium, a dose-dependent decrease in enzymatic activity was observed and was shown to be consistent with a comparable decrease caused by non-RF-radiation heating. Thus we observed only the well-known enzyme inhibition due to heating, rather than the previously reported enhancement attributed to RF-radiation exposure.

Di Carlo A, White N, Guo F, Garrett P, Litovitz T. Chronic electromagnetic field exposure decreases HSP70 levels and lowers cytoprotection. *J. Cell. Biochem.* 84: 447-454, 2002.

Electromagnetic field (EMF) exposures have been shown to induce heat shock proteins (HSPs), which help to maintain the conformation of cellular proteins during periods of stress. We have previously reported that short-term exposure of chick embryos to either 60 Hz (extremely low frequency: ELF), or radio-frequency (RF: 915 MHz) EMFs induce protection against hypoxia. Experiments presented in the current report are based on a study in which long-term (4 days), continuous exposure to ELF-EMFs *decreased* protection against ultraviolet radiation. Based on this result, it was hypothesized that de-protection against hypoxia should also occur following long-term, continuous, or daily, repeated exposures to EMFs. To test this hypothesis, chick embryos were exposed to ELF-EMFs (8 μ T) continuously for 4 days, or to ELF or RF (3.5 mW incident power)- EMFs repeated daily (20, 30, or 60 min once or twice daily for 4 days). Several of the exposure protocols yielded embryos that had statistically significant decreases in protection against hypoxic stress (continuous and 30 or 60 min ELF twice daily; or 30 or 60 min once daily RF). This is consistent with our finding that following 4 days of ELF-EMF exposure, HSP70 levels decline by 27% as compared to controls. In addition, the superposition of ELF-EM noise, previously shown to minimize ELF-EMF induced hypoxia protection, inhibited hypoxia de-protection caused by long term, continuous ELF or daily, repeated RF exposures. This EMF-induced decrease in HSP70 levels and resulting decline in cytoprotection suggests a mechanism by which daily exposure (such as might be experienced by mobile phone users) could enhance the probability of cancer and other diseases.

Diem E, Schwarz C, Adlkofer F, Jahn O, Rudiger H. Non-thermal DNA breakage by mobile-phone radiation (1800MHz) in human fibroblasts and in transformed GFSH-R17 rat granulosa cells in vitro. *Mutat Res.* 583:178-183, 2005.

Cultured human diploid fibroblasts and cultured rat granulosa cells were exposed to intermittent and continuous radiofrequency electromagnetic fields (RF-EMF) used in mobile phones, with different specific absorption rates (SAR) and different mobile-phone modulations. DNA strand breaks were determined by means of the alkaline and neutral comet assay. RF-EMF exposure (1800MHz; SAR 1.2 or 2W/kg; different modulations; during 4, 16 and 24h; intermittent 5min on/10min off or continuous wave) induced DNA single- and double-strand breaks. Effects occurred after 16h exposure in both cell types and after different mobile-phone modulations. The intermittent exposure showed a stronger effect in the comet assay than continuous exposure. Therefore we conclude that the induced DNA damage cannot be based on thermal effects.

Divan HA, Kheifets L, Obel C, Olsen J. Prenatal and Postnatal Exposure to Cell Phone Use and Behavioral Problems in Children. *Epidemiology.* 2008 May 7 [Epub ahead of print]

BACKGROUND:: The World Health Organization has emphasized the need for research into the possible effects of radiofrequency fields in children. We examined the association between prenatal and postnatal exposure to cell phones and behavioral problems in young children. **METHODS::** Mothers were recruited to the Danish National Birth Cohort early in pregnancy. When the children of those pregnancies reached 7 years of age in 2005 and 2006, mothers were asked to complete a questionnaire regarding the current health and behavioral status of children, as well as past exposure to cell phone use. Mothers evaluated the child's behavior problems using the Strength and Difficulties Questionnaire. **RESULTS::** Mothers of 13,159 children completed the follow-up questionnaire reporting their use of cell phones during pregnancy as well as current cell phone use by the child. Greater odds ratios for behavioral problems were observed for children who had possible prenatal or postnatal exposure to cell phone use. After adjustment for potential confounders, the odds ratio for a higher overall behavioral problems score was 1.80 (95% confidence interval = 1.45-2.23) in children with both prenatal and postnatal exposure to cell phones. **CONCLUSIONS::** Exposure to cell phones prenatally-and, to a lesser degree, postnatally-was associated with behavioral difficulties such as emotional and hyperactivity problems around the

age of school entry. These associations may be noncausal and may be due to unmeasured confounding. If real, they would be of public health concern given the widespread use of this technology.

Djeridane Y, Touitou Y, de Seze R. Influence of Electromagnetic Fields Emitted by GSM-900 Cellular Telephones on the Circadian Patterns of Gonadal, Adrenal and Pituitary Hormones in Men. *Radiat Res.* 169(3):337-343, 2008.

The potential health risks of radiofrequency electromagnetic fields (RF EMFs) emitted by mobile phones are currently of considerable public interest. The present study investigated the effect of exposure to 900 MHz GSM radiofrequency radiation on steroid (cortisol and testosterone) and pituitary (thyroid-stimulating hormone, growth hormone, prolactin and adrenocorticotropin) hormone levels in 20 healthy male volunteers. Each subject was exposed to RF EMFs through the use of a cellular phone for 2 h/day, 5 days/ week, for 4 weeks. Blood samples were collected hourly during the night and every 3 h during the day. Four sampling sessions were performed at 15-day intervals: before the beginning of the exposure period, at the middle and the end of the exposure period, and 15 days later. Parameters evaluated included the maximum serum concentration, the time of this maximum, and the area under the curve for hormone circadian patterns. Each individual's pre-exposure hormone concentration was used as his control. All hormone concentrations remained within normal physiological ranges. The circadian profiles of prolactin, thyroid-stimulating hormone, adrenocorticotropin and testosterone were not disrupted by RF EMFs emitted by mobile phones. For growth hormone and cortisol, there were significant decreases of about 28% and 12%, respectively, in the maximum levels when comparing the 2-week (for growth hormone and cortisol) and 4-week (for growth hormone) exposure periods to the pre-exposure period, but no difference persisted in the postexposure period. Our data show that the 900 MHz EMF exposure, at least under our experimental conditions, does not appear to affect endocrine functions in men.

Donnellan M, McKenzie DR, French PW, Effects of exposure to electromagnetic radiation at 835 MHz on growth, morphology and secretory characteristics of a mast cell analogue, RBL-2H3. *Cell Biol Int* 21:427-439, 1997.

A mast cell line, RBL-2H3, was exposed to 835 MHz for 20 minutes, three times per day for 7 days at a power density of 8.1 +/- 3 mW/cm². From day 4 onwards, it was observed that the rate of DNA synthesis and cell replication increased, that actin distribution and cell morphology became altered, and the amount of beta-hexosaminidase (a marker of granule secretion) released in response to a calcium ionophore was significantly enhanced, in comparison to unexposed cultures. There were no effects seen on levels of cytoskeletal protein synthesis or of beta-actin mRNA. Morphological changes persisted following subculture for at least 7 days in the absence of further exposure. It is hypothesized that effects of exposure to an electromagnetic field at 835 MHz may be mediated via a signal transduction pathway.

Dubreuil D, Jay T, Edeline JM. Does head-only exposure to GSM-900 electromagnetic fields affect the performance of rats in spatial learning tasks? *Behav Brain Res* 129(1-2):203-210, 2002.

The rapid expansion of mobile communication has generated intense interest, but has also fuelled ongoing concerns. In both humans and animals, radiofrequency radiations are suspected to affect cognitive functions. More specifically, several studies performed in rodents have suggested that spatial learning can be impaired by electromagnetic field exposure. However, none of these previous studies have simulated the common conditions of GSM mobile phones use. This study is the first using a head-only exposure system emitting a 900-MHz GSM electromagnetic field (pulsed at 217 Hz). The two behavioural tasks that were evaluated here have been used previously to demonstrate performance deficits in spatial learning after electromagnetic field exposure: a classical radial maze elimination task and a spatial navigation task in an open-field arena (dry-land version of the Morris water maze). The performances of rats exposed for 45 min to a 900-MHz electromagnetic field (1 and 3.5 W/kg) were compared to those of sham-exposed and cage-control rats. There were no differences among exposed, sham, and cage-control rats in the two spatial learning tasks. The discussion focuses on the potential reasons that led previous studies to conclude that learning deficits do occur after electromagnetic field exposure.

Dubreuil D, Jay T, Edeline JM. Head-only exposure to GSM 900-MHz electromagnetic fields does not alter rat's memory in spatial and non-spatial tasks. *Behav Brain Res.* 145(1-2):51-61, 2003.

Over the last decade, exposure to high frequency (2450 MHz) electromagnetic fields (EMFs) has been found to induce performance deficit in rodents in spatial memory tasks. As concern was expressed about potential biological effects of

mobile communication microwaves, studies testing the effects of signals such as GSM were required. In a previous study, using head-only exposure to 900 MHz GSM EMF, we could not demonstrate any behavioural deficit in two simple learning tasks. The present study aimed at extending these results with more complex spatial learning tasks and a non-spatial task. In a first experiment, rats were trained in a radial-arm maze with a 10-s confinement between each visited arm. In a second experiment, a 15-min intra-trial delay was introduced after four visited arms. In a third experiment, non-spatial memory was tested in an object recognition task. In all experiments, performance of the head-only exposed rats (1 and 3.5 W/kg) was compared with that of sham and control rats. In the first experiment, a slightly improved performance was found after 3.5 W/kg exposure, a result that was not observed in the delay-task. In the third experiment, although some effects on exploratory activity were found, recognition memory was unaffected in exposed rats. Altogether, this set of experiments provides no evidence indicating that spatial and non-spatial memory can be affected by a 45-min head-only exposure to 900 MHz GSM EMF.

Eberhardt JL, Persson BR, Brun AE, Salford LG, Malmgren LO. Blood-brain barrier permeability and nerve cell damage in rat brain 14 and 28 days after exposure to microwaves from GSM mobile phones. *Electromagn Biol Med.* 27(3):215-229, 2008.

We investigated the effects of global system for mobile communication (GSM) microwave exposure on the permeability of the blood-brain barrier and signs of neuronal damage in rats using a real GSM programmable mobile phone in the 900 MHz band. Ninety-six non-anaesthetized rats were either exposed to microwaves or sham exposed in TEM-cells for 2 h at specific absorption rates of average whole-body Specific Absorption Rates (SAR) of 0.12, 1.2, 12, or 120 mW/kg. The rats were sacrificed after a recovery time of either 14 or 28 d, following exposure and the extravasation of albumin, its uptake into neurons, and occurrence of damaged neurons was assessed. Albumin extravasation and also its uptake into neurons was seen to be enhanced after 14 d (Kruskal Wallis test: $p = 0.02$ and 0.002 , respectively), but not after a 28 d recovery period. The occurrence of dark neurons in the rat brains, on the other hand, was enhanced later, after 28 d ($p = 0.02$). Furthermore, in the 28-d brain samples, neuronal albumin uptake was significantly correlated to occurrence of damaged neurons (Spearman $r = 0.41$; $p < 0.01$).

Edelstyn N, Oldershaw A. The acute effects of exposure to the electromagnetic field emitted by mobile phones on human attention. *Neuroreport* 13(1):119-121, 2002.

The aim of our study was to investigate the effects of acute mobile phone exposure on a range of tasks which tapped capacity and processing speed within the attentional system. Thirty-eight healthy volunteers were randomly assigned to either an experimental group which was exposed to a connected mobile phone or a control group in which the mobile phone was switched off. Subjects remained blind to mobile phone status throughout duration of study. The experimental group were exposed to an electromagnetic field emitted by a 900 MHz mobile phone for 30 min. Cognitive performance was assessed at three points (prior to mobile phone exposure, at 15 and 30 min post-exposure) using six cognitive neuropsychological tests (digit span and spatial span forwards and backwards, serial subtraction and verbal fluency). Significant differences between the two groups were evident after 5 min on two tests of attentional capacity (digit span forwards and spatial span backwards) and one of processing speed (serial subtraction). In all three instances, performance was facilitated following mobile phone exposure. No deficits were evident. These findings are discussed in terms of possible functional and neuroanatomical bases.

Elhag MA, Nabil GM, Attia AM. Effects of electromagnetic field produced by mobile phones on the oxidant and antioxidant status of rats. *Pak J Biol Sci.* 10(23):4271-4274, 2007.

This study was designed to investigate the effect of EMR produced by GSM Mobile Phones (MP) on the oxidant and antioxidant status in rats. Rats were divided into three groups: (1) controls, (2) rats exposed to a fractionated dose of EMR (15 min day⁻¹ for four days) (EMR-F) and (3) rats exposed to an acute dose of EMR (EMR-A). A net drop in the plasma concentration of vitamin C (-47 and -59.8%) was observed in EMR-F and EMR-A groups, respectively, when compared to controls. While, a significant decrease in the levels of lipophilic antioxidant vitamins: vitamin E (-33 and -65.8%), vitamin A (-44.4 and -46.8%) was observed in EMR-F and EMR-A groups, respectively, when compared to controls. A net drop in plasma level of reduced glutathione (GSH) (-19.8 and -35.3%) was observed in EMR-F and EMR-A groups,

respectively. EMR exposure of rats produced a significant decrease in catalase (CAT) and superoxide dismutase (SOD) activities, with the values of these activities for EMR-A group is significantly lower than those of EMR-F. These results indicate that the effects of acute doses of EMR produced by mobile phones on the rat's antioxidant status is significantly higher than those of fractionated doses of the same type of radiation. On the basis of present results, it can be concluded that exposure to acute doses of EMR produced by mobile phones is more hazardous than that produced by fractionated doses of the same type of radiation.

Eliyahu I, Luria R, Hareuveny R, Margaliot M, Meiran N, Shani G.

Effects of radiofrequency radiation emitted by cellular telephones on the cognitive functions of humans.

Bioelectromagnetics. 2005 Nov 22; [Epub ahead of print]

The present study examined the effects of exposure to Electromagnetic Radiation emitted by a standard GSM phone at 890 MHz on human cognitive functions. This study attempted to establish a connection between the exposure of a specific area of the brain and the cognitive functions associated with that area. A total of 36 healthy right-handed male subjects performed four distinct cognitive tasks: spatial item recognition, verbal item recognition, and two spatial compatibility tasks. Tasks were chosen according to the brain side they are assumed to activate. All subjects performed the tasks under three exposure conditions: right side, left side, and sham exposure. The phones were controlled by a base station simulator and operated at their full power. We have recorded the reaction times (RTs) and accuracy of the responses. The experiments consisted of two sections, of 1 h each, with a 5 min break in between. The tasks and the exposure regimes were counterbalanced. The results indicated that the exposure of the left side of the brain slows down the left-hand response time, in the second-later-part of the experiment. This effect was apparent in three of the four tasks, and was highly significant in only one of the tests. The exposure intensity and its duration exceeded the common exposure of cellular phone users.

Eltiti S, Wallace D, Ridgewell A, Zougkou K, Russo R, Sepulveda F, Mirshekar-Syahkal D, Rasor P, Deeble R, Fox E. Does short-term exposure to mobile phone base station signals increase symptoms in individuals who report sensitivity to electromagnetic fields? A double-blind randomized provocation study. **Environ Health Perspect.** 115(11):1603-1608, 2007.

BACKGROUND: Individuals with idiopathic environmental illness with attribution to electromagnetic fields (IEI-EMF) believe they suffer negative health effects when exposed to electromagnetic fields from everyday objects such as mobile phone base stations. **OBJECTIVES:** This study used both open provocation and double-blind tests to determine if sensitive and control individuals experience more negative health effects when exposed to base station-like signals compared with sham. **METHODS:** Fifty-six self-reported sensitive and 120 control participants were tested in an open provocation test. Of these, 12 sensitive and 6 controls withdrew after the first session. The remainder completed a series of double-blind tests. Subjective measures of well-being and symptoms as well as physiological measures of blood volume pulse, heart rate, and skin conductance were obtained. **RESULTS:** During the open provocation, sensitive individuals reported lower levels of well-being in both the global system for mobile communication (GSM) and universal mobile telecommunications system (UMTS) compared with sham exposure, whereas controls reported more symptoms during the UMTS exposure. During double-blind tests the GSM signal did not have any effect on either group. Sensitive participants did report elevated levels of arousal during the UMTS condition, whereas the number or severity of symptoms experienced did not increase. Physiological measures did not differ across the three exposure conditions for either group. **CONCLUSIONS:** Short-term exposure to a typical GSM base station-like signal did not affect well-being or physiological functions in sensitive or control individuals. Sensitive individuals reported elevated levels of arousal when exposed to a UMTS signal. Further analysis, however, indicated that this difference was likely to be due to the effect of order of exposure rather than the exposure itself.

Erogul O, Oztas E, Yildirim I, Kir T, Aydur E, Komesli G, Irkilata HC, Irmak MK, Peker AF. Effects of electromagnetic radiation from a cellular phone on human sperm motility: an in vitro study. **Arch Med Res.** 37(7):840-843, 2006.

BACKGROUND: There has been growing public concern on the effects of electromagnetic radiation (EMR) emitted by cellular phones on human health. Many studies have recently been published on this topic. However, possible consequences of the cellular phone usage on human sperm parameters have not been investigated adequately. **METHODS:** A total number of 27 males were enrolled in the study. The semen sample obtained from each participant was divided equally into two parts. One of the specimens was exposed to EMR emitted by an activated 900 MHz cellular phone, whereas the other was not. The concentration and motility of the specimens were compared to analyze the effects of EMR. Assessment of sperm movement in all specimens was performed using four criteria: (A) rapid progressive, (B) slow progressive, (C) nonprogressive, (D) no motility. **RESULTS:** Statistically significant changes were observed in the rapid progressive, slow progressive and no-motility categories of sperm movement. EMR exposure caused a subtle decrease in the rapid progressive and slow progressive sperm movement. It also caused an increase in the no-motility category of sperm movement. There was no statistically significant difference in the sperm concentration between two groups. **CONCLUSIONS:** These data suggest that EMR emitted by cellular phone influences human sperm motility. In addition to these acute adverse effects of EMR on sperm motility, long-term EMR exposure may lead to behavioral or structural changes of the male germ cell. These effects may be observed later in life, and they are to be investigated more seriously.

Esen F, Esen H Effect of electromagnetic fields emitted by cellular phones on the latency of evoked electrodermal activity. Int J Neurosci. 116(3):321-329, 2006.

The widespread use of cellular phones raises the question of their possible adverse biological effects, especially on the central nervous system (CNS). Therefore, the authors examined the effect of electromagnetic fields emitted by cellular phones (CPEMFs) on the evoked neuronal activity of CNS relating to generation and representation of electrodermal activity (EDA), an index of sympathetic nervous system activity. EDA (skin resistance response; SRR) latency was lengthened approximately 200 ms with CPEMFs exposure irrespective of the head site next to mobile phone used. Hemispheric asymmetry of EDA-2 pathway, which is represented by shorter SRR latency in the right hand of the right hand responders, was also distorted with CPEMFs. Because the CNS regions including EDA-2 are also involved in tasks of motor timing and time estimation, delayed response in this neuronal network due to CPEMFs exposure may increase the response time of mobile phone users. Therefore, the findings point to the potential risks of mobile phones on the function of CNS and consequently, possible increase in the risk of phone-related driving hazards.

Eulitz, C, Ullsperger, P, Freude, G, Elbert ,T, Mobile phones modulate response patterns of human brain activity. Neuroreport 9(14):3229-3232, 1998.

Mobile phones emit a pulsed high-frequency electromagnetic field (PEMF) which may penetrate the scalp and the skull. Increasingly, there is an interest in the interaction of this pulsed microwave radiation with the human brain. Our investigations show that these electromagnetic fields alter distinct aspects of the brain's electrical response to acoustic stimuli. More precisely, our results demonstrate that aspects of the induced but not the evoked brain activity during PEMF exposure can be different from those not influenced by PEMF radiation. This effect appears in higher frequency bands when subjects process task-relevant target stimuli but was not present for irrelevant standard stimuli. As the induced brain activity in higher frequency bands has been proposed to be a correlate of coherent high-frequency neuronal activity, PEMF exposure may provide means to systematically alter the pattern fluctuations in neural mass activity.

Falzone N, Huyser C, Fourie F, Toivo T, Leszczynski D, Franken D. In vitro effect of pulsed 900 MHz GSM radiation on mitochondrial membrane potential and motility of human spermatozoa. Bioelectromagnetics. 2007 Dec 28 [Epub ahead of print]

Ejaculated, density purified, human spermatozoa were exposed to pulsed 900 MHz GSM mobile phone radiation at two specific absorption rate levels (SAR 2.0 and 5.7 W/kg) and compared with controls over time. Change in sperm mitochondrial membrane potential was analysed using flow cytometry. Sperm motility was determined by computer assisted sperm analysis (CASA). There was no effect of pulsed 900 MHz GSM radiation on mitochondrial membrane potential. This was also the case for all kinematic parameters assessed at a SAR of 2.0 W/kg. However, over time, the two kinematic parameters straight line velocity (VSL) and beat-cross frequency (BCF) were significantly impaired ($P < 0.05$)

after the exposure at SAR 5.7 W/kg and no exposure by time interaction was present. This result should not be ascribed to thermal effects, due to the cooling methods employed in the RF chamber and temperature control within the incubator.

Faucon G, Le Bouquin Jeannes R, Maby E. Short-term effects of GSM mobiles phones on spectral components of the human electroencephalogram. Conf Proc IEEE Eng Med Biol Soc. 2006;1(1):3751-3754.

The aim of the study was to investigate whether the GSM (global system for mobile) signals affect the electrical activity of the human brain. Nine healthy subjects and six temporal epileptic patients were exposed to radiofrequencies emitted by a GSM mobile phone signals. Electroencephalographic (EEG) signals were recorded using surface electrodes with and without radiofrequency. In order to obtain a reference, a control session was also carried out. The spectral attributes of the EEG signals recorded by surface electrodes were analyzed. The significant decrease of spectral correlation coefficients under radiofrequency influence showed that the GSM signal altered the spectral arrangement of the EEG activity for healthy subjects as well as epileptic patients. For the healthy subjects, the EEG spectral energy decreased on the studied frequency band [0-40 Hz] and more precisely on occipital electrodes for the alpha-band. For the epileptic patients, these modifications were demonstrated by an increase of the power spectral density of the EEG signal. Nevertheless, these biological effects on the EEG are not sufficient to put forward some electrophysiological hypothesis.

Fejes I, Za Vaczki Z, Szollosi J, Kolosza R S, Daru J, Kova Cs L, Pa L A Is there a relationship between cell phone use and semen quality? Arch Androl. 51(5):385-393, 2005.

This study was conducted to determine a possible relationship between regular cell phone use and different human semen attributes. The history-taking of men in our university clinic was supplemented with questions concerning cell phone use habits, including possession, daily standby position and daily transmission times. Semen analyses were performed by conventional methods. Statistics were calculated with SPSS statistical software. A total of 371 were included in the study. The duration of possession and the daily transmission time correlated negatively with the proportion of rapid progressive motile sperm ($r = -0.12$ and $r = -0.19$, respectively), and positively with the proportion of slow progressive motile sperm ($r = 0.12$ and $r = 0.28$, respectively). The low and high transmitter groups also differed in the proportion of rapid progressive motile sperm (48.7% vs. 40.6%). The prolonged use of cell phones may have negative effects on the sperm motility characteristics.

Ferreira AR, Knakievicz T, de Bittencourt Pasquali MA, Gelain DP, Dal-Pizzol F, Fernandez CE, de Almeida de Salles AA, Ferreira HB, Moreira JC. Ultra high frequency-electromagnetic field irradiation during pregnancy leads to an increase in erythrocytes micronuclei incidence in rat offspring. Life Sci. 2006 Aug 23; [Epub ahead of print]

Mobile telephones and their base stations are an important ultra high frequency-electromagnetic field (UHF-EMF) source and their utilization is increasing all over the world. Epidemiological studies suggested that low energy UHF-EMF emitted from a cellular telephone may cause biological effects, such as DNA damage and changes on oxidative metabolism. An in vivo mammalian cytogenetic test, the micronucleus (MN) assay, was used to investigate the occurrence of chromosomal damage in erythrocytes from rat offspring exposed to a non-thermal UHF-EMF from a cellular phone during their embryogenesis; the irradiated group showed a significant increase in MN occurrence. In order to investigate if UHF-EMF could also alter oxidative parameters in the peripheral blood and in the liver - an important hematopoietic tissue in rat embryos and newborns - we also measured the activity of antioxidant enzymes, quantified total sulfhydryl content, protein carbonyl groups, thiobarbituric acid-reactive species and total non-enzymatic antioxidant defense. No significant differences were found in any oxidative parameter of offspring blood and liver. The average number of pups in each litter has also not been significantly altered. Our results suggest that, under our experimental conditions, UHF-EMF is able to induce a genotoxic response in hematopoietic tissue during the embryogenesis through an unknown mechanism.

Ferreri F, Curcio G, Pasqualetti P, De Gennaro L, Fini R, Rossini PM. Mobile phone emissions and human brain excitability. Ann Neurol. 2006 Jun 26; [Epub ahead of print]

OBJECTIVE: To test-via Transcranial Magnetic Stimulation (TMS)-the excitability of each brain hemisphere after 'real' or 'sham' exposure to the electromagnetic field (EMF) generated by a mobile phone operating in the Global System for Mobile Communication (GSM). **METHODS:** Fifteen male volunteers attended two experimental sessions, one week apart, in a cross-over, double-blind paradigm. In one session the signal was turned ON (EMF-on, real exposure), in the other it was turned OFF (EMF-off, sham exposure), for 45 minutes. Motor Evoked Potentials (MEPs) were recorded using a paired-pulse paradigm (testing intracortical excitability with 1 to 17 ms interstimulus intervals), both before and at different times after exposure to the EMF. Short Intracortical Inhibition (SICI) and Facilitation (ICF) curves were evaluated both on the exposed and non-exposed hemispheres. Tympanic temperature was collected during each session. **RESULTS:** The intracortical excitability curve becomes significantly modified during real exposure, with SICI being reduced and ICF enhanced in the acutely exposed brain hemisphere as compared to the contralateral, non-exposed hemisphere or to sham exposure. Tympanic temperature showed no significant main effect or interactions. **INTERPRETATION:** These results demonstrate that GSM-EMFs modify brain excitability. Possible implications and applications are discussed.

Finnie JW, Blumbergs PC, Manavis J, Utteridge TD, Gebiski V, Swift JG, Vernon-Roberts B, Kuchel TR. Effect of global system for mobile communication (gsm)-like radiofrequency fields on vascular permeability in mouse brain. *Pathology* 33(3):338-340, 2001.

The effect of global system for mobile communication (GSM) radiofrequency fields on vascular permeability in the brain was studied using a purpose-designed exposure system at 898.4 MHz. Mice (n= 30) were given a single far field, whole body exposure for 60 minutes at a specific absorption rate of 4 W/kg. Control mice were also sham-exposed (n = 10) or permitted free movement in a cage (n = 10) to exclude any stress-related effects. Vascular permeability changes were detected using albumin immunohistochemistry and the efficacy of this vascular tracer was confirmed with a positive control group exposed to a clostridial toxin known to increase vascular permeability in the brain. No significant difference in albumin extravasation was detected between any of the groups at the light microscope level using the albumin marker.

Finnie JW, Blumbergs PC, Manavis J, Utteridge TD, Gebiski V, Davies RA, Vernon-Roberts B, Kuchel TR. Effect of long-term mobile communication microwave exposure on vascular permeability in mouse brain. *Pathology* 34(4):344-347, 2002.

AIMS: To study the effect of long-term exposure to global system for mobile communication (GSM) radiofrequency fields on vascular permeability in murine brains. **METHODS:** Using a purpose-designed exposure system at 900 MHz, mice were given a 60-minute far-field, whole body exposure on each of 5 days per week for 104 weeks at specific absorption rates (SAR) of 0.25, 1.0, 2.0 and 4.0 W/kg. Control mice were sham-exposed or permitted free movement in a cage to evaluate any stress-related effects. Albumin immunohistochemistry was used to detect increased vascular permeability and the efficacy of the vascular tracer was confirmed with a positive control group exposed to a clostridial toxin known to increase vascular permeability in the brain. **RESULTS:** In all exposed and control groups, albumin extravasation was minimal, often leptomeningeal, and was deemed insignificant as a maximum of three capillaries or venules in a given brain showed leakage from the very many blood vessels present in the three coronal brain sections. **CONCLUSIONS:** These results suggest that prolonged exposure to mobile telephone-type radiation produces negligible disruption to blood-brain barrier integrity at the light microscope level using endogenous albumin as a vascular tracer.

Finnie JW. Expression of the immediate early gene, c-fos, in mouse brain after acute global system for mobile communication microwave exposure. *Pathology*. 37(3):231-233, 2005.

AIMS: To study the effect of acute exposure to global system for mobile communication radiofrequency fields on immediate early gene, c-fos, expression in the brain. **METHODS:** Using a purpose-designed exposure system at 900 MHz, mice were given a single, far-field, whole body exposure for 60 minutes at a specific absorption rate of 4 W/kg. Control mice were sham-exposed or freely mobile in a cage without further restraint. c-fos protein expression was detected immunohistochemically in perfusion-fixed brains. **RESULTS:** Activation of c-fos in exposed and sham-exposed brains was comparable, but was greatly increased compared with freely moving controls. **CONCLUSION:** These results suggest that the majority of the acute genomic response detected by c-fos expression was due to immobilisation rather than irradiation.

Finnie JW, Blumbergs PC, Cai Z, Manavis J, Kuchel TR. Effect of mobile telephony on blood-brain barrier permeability in the fetal mouse brain. Pathology. 38(1):63-65, 2006.

AIMS: To study the effect of mobile telephone exposure on blood-brain barrier (BBB) permeability in the immature brain. **METHODS:** Using a purpose-designed exposure system at 900 MHz, pregnant mice were given a single, far-field, whole body exposure at a specific absorption rate of 4 W/kg for 60 min/day from day 1 to day 19 of gestation. Pregnant control mice were sham-exposed or freely mobile in a cage without further restraint and a positive control group with cadmium-induced BBB damage was also included. Immediately prior to parturition on gestational day 19, fetal heads were collected, fixed in Bouin's fixative and paraffin embedded. Disruption of BBB integrity was detected immunohistochemically using endogenous albumin as a vascular tracer in cerebral cortex, thalamus, basal ganglia, hippocampus, cerebellum, midbrain and medulla. **RESULTS:** No albumin extravasation was found in exposed or control brains. **CONCLUSION:** In this animal model, whole of gestation exposure to global system for mobile communication-like radiofrequency fields did not produce any increase in vascular permeability in the fetal brain regions studied using endogenous albumin as a light microscopic immunohistochemical marker.

Finnie JW, Cai Z, Blumbergs PC, Manavis J, Kuchel TR. Expression of the immediate early gene, c-fos, in fetal brain after whole of gestation exposure of pregnant mice to global system for mobile communication microwaves. Pathology. 38(4):333-335, 2006.

Aims: To study immediate early gene, c-fos, expression as a marker of neural stress after whole of gestation exposure of the fetal mouse brain to mobile telephone-type radiofrequency fields. **Methods:** Using a purpose-designed exposure system at 900 MHz, pregnant mice were given a single, far-field, whole body exposure at a specific absorption rate of 4 W/kg for 60 min/day from day 1 to day 19 of gestation. Pregnant control mice were sham-exposed or freely mobile in a cage without further restraint. Immediately prior to parturition on gestational day 19, fetal heads were collected, fixed in 4% paraformaldehyde and paraffin embedded. Any stress response in the brain was detected by c-fos immunohistochemistry in the cerebral cortex, basal ganglia, thalamus, hippocampus, midbrain, cerebellum and medulla. **Results:** c-fos expression was of limited, but consistent, neuroanatomical distribution and there was no difference in immunoreactivity between exposed and control brains. **Conclusion:** In this animal model, no stress response was detected in the fetal brain using c-fos immunohistochemistry after whole of gestation exposure to mobile telephony.

Finnie JW, Chidlow G, Blumbergs PC, Manavis J, Cai Z.

Heat shock protein induction in fetal mouse brain as a measure of stress after whole of gestation exposure to mobile telephony radiofrequency fields. Pathology. 41(3):276-279, 2009.

Aim: To determine whether whole of gestation exposure of fetal mouse brain to mobile telephone radiofrequency fields produces a stress response detectable by induction of heat shock proteins (HSPs). **Methods:** Using a purpose-designed exposure system at 900 MHz, pregnant mice were given a single, far-field, whole body exposure at a specific absorption rate of 4 W/kg for 60 min/day from day 1 to day 19 of gestation. Control mice were sham-exposed or freely mobile in a cage to control for any stress caused by restraint in the exposure module. Immediately prior to parturition on day 19, fetal brains were collected, fixed in 4% paraformaldehyde and paraffin-embedded. Three coronal sections encompassing a wide range of anatomical regions were cut from each brain and any stress response detected by immunostaining for HSP25, 32 and 70. **Results:** There was no induction of HSP32 or 70 in any brains, while HSP25 expression was limited to two brainstem nuclei and occurred consistently in exposed and non-exposed brains. **Conclusion:** Whole of gestation exposure of fetal mouse brains to mobile phone radiofrequency fields did not produce any stress response using HSPs as an immunohistochemical marker.

Finnie JW, Blumbergs PC, Cai Z, Manavis J. Expression of the water channel protein, aquaporin-4, in mouse brains exposed to mobile telephone radiofrequency fields. Pathology. 2009 Apr 26:1-3. [Epub ahead of print]

Aim: To determine whether exposure to mobile telephone radiofrequency (RF) fields, either acutely or long-term, produces up-regulation of the water channel protein, aquaporin-4 (AQP-4). **Methods:** Using a purpose-designed exposure system at 900 MHz, mice were given a single, far-field whole body exposure at a specific absorption rate of 4 W/kg for 60 minutes or a similar exposure on 5 successive days/week for 104 weeks. Control mice were sham-exposed or freely mobile in a cage to control for any stress caused by restraint in the exposure module. A positive control group was given a clostridial toxin known to cause microvascular endothelial injury, severe vasogenic oedema and upregulation of AQP-4.

Brains were perfusion fixed with 4% paraformaldehyde, coronal sections cut from six levels, and immunostained for the principal water channel protein in brain, AQP-4. Results: There was no increase in AQP-4 expression in brains exposed to mobile phone microwaves compared to control (sham exposed and freely moving caged mice) brains after short or protracted exposure, while AQP-4 was substantially upregulated in the brains of mice given the clostridial toxin. Conclusion: Brains exposed to mobile telephone RF fields for a short (60 minutes) or long (2 years) duration did not show any immunohistochemically detectable up-regulation of the water channel protein, AQP-4, suggesting that there was no significant increase in blood-brain barrier permeability.

Forgacs Z, Somosy Z, Kubinyi G, Bakos J, Hudak A, Surjan A, Thurocz G. Effect of whole-body 1800MHz GSM-like microwave exposure on testicular steroidogenesis and histology in mice. Reprod Toxicol. 2006 Jan 21; [Epub ahead of print]

The aim of our study was to evaluate the possible effects of whole-body 1800MHz GSM-like microwave exposure on male reproduction. After repeated exposure of mice to microwaves at 0.018-0.023W/kg whole-body specific energy absorption rate (SAR) an elevated serum testosterone level was measured, but no microwave exposure related histopathological alteration could be detected in the reproductive organs. The in vitro steroidogenic response of 48h Leydig cell cultures obtained from exposed animals did not differ from the controls, suggesting that Leydig cells were not the primary targets of the applied microwave exposure or direct action of microwaves on Leydig cells was temporary only. In exposed animals the red blood cell count and volume of packed red cells were also increased. Further investigations are required to clarify the mechanism of action of the applied microwave exposure on male mice, as well as to establish the biological significance of the observed phenomena.

Franke H, Streckert J, Bitz A, Goeke J, Hansen V, Ringelstein EB, Nattkamper H, Galla HJ, Stogbauer F Effects of Universal Mobile Telecommunications System (UMTS) Electromagnetic Fields on the Blood-Brain Barrier In Vitro. Radiat Res. 164(3):258-269, 2005.

The extensive use of mobile phone communication has raised public concerns about adverse health effects of radiofrequency (RF) electromagnetic fields (EMFs) in recent years. A central issue in this discussion is the question whether EMFs enhance the permeability of the blood-brain barrier (BBB). Here we report an investigation on the influence of a generic UMTS (Universal Mobile Telecommunications System) signal on barrier tightness, transport processes and the morphology of porcine brain microvascular endothelial cell cultures (PBEC) serving as an in vitro model of the BBB. An exposure device with integrated online monitoring system was developed for simultaneous exposure and measuring of transendothelial electrical resistance (TEER) to determine the tightness of the BBB. PBEC were exposed continuously for up to 84 h at an average electric-field strength of 3.4-34 V/m (maximum 1.8 W/kg) ensuring athermal conditions. We did not find any evidence of RF-field-induced disturbance of the function of the BBB. After and during exposure, the tightness of the BBB quantified by (14)C-sucrose and serum albumin permeation as well as by TEER remained unchanged compared to sham-exposed cultures. Permeation of transporter substrates at the BBB as well as the localization and integrity of the tight-junction proteins occludin and ZO1 were not affected either.

Franzellitti S, Valbonesi P, Contin A, Biondi C, Fabbri E. HSP70 expression in human trophoblast cells exposed to different 1.8 Ghz mobile phone signals. Radiat Res. 170(4):488-497, 2008.

The heat-shock proteins (HSPs) are important cellular stress markers and have been proposed as candidates to infer biological effects of high-frequency electromagnetic fields (EMFs). In the current study, HSP70 gene and protein expression were evaluated in cells of the human trophoblast cell line HTR-8/SVneo after prolonged exposure (4 to 24 h) to 1.8 GHz continuous-wave (CW) and different GSM signals (GSM-217Hz and GSM-Talk) to assess the possible effects of time and modulation schemes on cell responses. Inducible HSP70 protein expression was not modified by high-frequency EMFs under any condition tested. The inducible HSP70A, HSP70B and the constitutive HSC70 transcripts did not change in cells exposed to high-frequency EMFs with the different modulation schemes. Instead, levels of the inducible HSP70C transcript were significantly enhanced after 24 h exposure to GSM-217Hz signals and reduced after 4 and 16 h exposure to GSM-Talk signals. As in other cell systems, in HTR-8/SVneo cells the response to high-frequency

EMFs was detected at the mRNA level after exposure to amplitude-modulated GSM signals. The present results suggest that the expression analysis for multiple transcripts, though encoding the same or similar protein products, can be highly informative and may account for subtle changes not detected at the protein level.

French PW, Donnellan M, McKenzie DR, Electromagnetic radiation at 835 MHz changes the morphology and inhibits proliferation of a human astrocytoma cell line. *Bioelectrochem Bioenerg* 43:13-18, 1997.

A human astrocytoma cell line, U-87 MG, was exposed to 835 MHz electromagnetic radiation for 20 min, 3 times per day for 7 days, at a power density of either $40 \pm 15 \text{ mWcm}^{-2}$ or $8.1 \pm 3 \text{ mWcm}^{-2}$. At the low power density, it was observed that the rate of DNA synthesis decreased, and that the cells flattened and spread out in comparison to unexposed culture. At 40 mWcm^{-2} , there were no effects seen on cell proliferation, but alteration in cell morphology included increased cell spreading and also the appearance of actin-containing blebs at localized sites on the membrane. It is hypothesised that 835 MHz radiation at low power density may be affecting a signal transduction pathway involved in cell proliferation.

Freude, G, Ullsperger, P, Eggert, S, Ruppe, I, Effects of microwaves emitted by cellular phones on human slow brain potentials. *Bioelectromagnetics* 19(6):384-387, 1998.

The influence of electromagnetic fields (EMF) emitted by cellular phones on preparatory slow brain potentials (SP) was studied in two different experimental tasks: In the first, healthy male human subjects had to perform simple self-paced finger movements to elicit a Bereitschaftspotential; in the second, they performed a complex and cognitive demanding visual monitoring task (VMT). Both tasks were performed with and without EMF exposure in counterbalanced order. Whereas subjects' performance did not differ between the EMF exposure conditions, SP parameters were influenced by EMF in the VMT: EMF exposure effected a significant decrease of SPs at central and temporo-parieto-occipital brain regions, but not at the frontal one. In the simple finger movement task, EMF did not affect the Bereitschaftspotential.

Freude, G, Ullsperger, P, Eggert, S, Ruppe, I, Microwaves emitted by cellular telephones affect human slow brain potentials. *Eur J Appl Physiol* 81(1-2):18-27, 2000.

The influence of electromagnetic fields (EMF) emitted by cellular telephones on preparatory slow brain potentials (SP) was studied in two experiments, about 6 months apart. In the first experiment, a significant decrease of SP was found during exposure to EMF in a complex visual monitoring task (VMT). This effect was replicated in the second experiment. In addition to the VMT, EMF effects on SP were analysed in two further, less demanding tasks: in a simple finger movement task to elicit a Bereitschaftspotential (BP) and in a two-stimulus task to elicit a contingent negative variation (CNV). In comparison to the VMT, no significant main EMF effects were found in BP and CNV tasks. The results accounted for a selective EMF effect on particular aspects of human information processing, but did not indicate any influence on human performance, well-being and health.

Friedman J, Kraus S, Hauptman Y, Schiff Y, Seger R. Mechanism of a short-term ERK activation by electromagnetic fields at mobile phone frequency. *Biochem J*. 2007 Apr 25; [Epub ahead of print]

The exposure to non-thermal microwave electromagnetic field generated by mobile phones affects the expression of many proteins. This effect on transcription and protein stability can be mediated by the mitogen-activated protein kinase (MAPK) cascades, which serve as central signaling pathways, and govern essentially all stimulated cellular processes. Indeed, a long-term exposure of cells to mobile phone irradiation results in the activation of p38MAPKs as well as the ERK/MAPKs. Here we studied the immediate effect of irradiation on the MAPK cascades, and found that ERKs, but not stress related MAPKs are rapidly activated in response to various frequencies and intensities. Using signaling inhibitors we delineated the mechanism that is involved in this activation. We found that the first step is mediated in the plasma membrane by NADH oxidase, which rapidly generates reactive oxygen species (ROS). These ROS then directly stimulate matrix metalloproteinases and allow them to cleave and release heparin binding-EGF. This secreted factor, activates EGF receptor, which in turn further activates the ERK cascade. Thus, this study demonstrates for the first time a detailed molecular mechanism by which electromagnetic irradiation by mobile phones induces the activation of the ERK cascade and thereby induces transcription and other cellular processes.

Fritze K, Wiessner C, Kuster N, Sommer C, Gass P, Hermann DM, Kiessling M, Hossmann KA, Effect of global system for mobile communication microwave exposure on the genomic response of the rat brain. *Neuroscience* 81(3):627-639, 1997.

The acute effect of global system for mobile communication (GSM) microwave exposure on the genomic response of the central nervous system was studied in rats by measuring changes in the messenger RNAs of hsp70, the transcription factor genes c-fos and c-jun and the glial structural gene GFAP using in situ hybridization histochemistry. Protein products of transcription factors, stress proteins and marker proteins of astroglial and microglial activation were assessed by immunocytochemistry. Cell proliferation was evaluated by bromodeoxyuridine incorporation. A special GSM radiofrequency test set, connected to a commercial cellular phone operating in the discontinuous transmission mode, was used to simulate GSM exposure. The study was conducted at time averaged and brain averaged specific absorption rates of 0.3 W/kg (GSM exposure), 1.5 W/kg (GSM exposure) and 7.5 W/kg (continuous wave exposure), respectively. Immediately after exposure, in situ hybridization revealed slight induction of hsp70 messenger RNA in the cerebellum and hippocampus after 7.5 W/kg exposure, but not at lower intensities. A slightly increased expression of c-fos messenger RNA was observed in the cerebellum, neocortex and piriform cortex of all groups subjected to immobilization, but no differences were found amongst different exposure conditions. C-jun and GFAP messenger RNAs did not increase in any of the experimental groups. 24 h after exposure, immunocytochemical analysis of FOS and JUN proteins (c-FOS, FOS B, c-JUN JUN B, JUN D), of HSP70 or of KROX-20 and -24 did not reveal any alterations. Seven days after exposure, neither increased cell proliferation nor altered expression of astroglial and microglial marker proteins were observed. In conclusion, acute high intensity microwave exposure of immobilized rats may induce some minor stress response but does not result in lasting adaptive or reactive changes of the brain.

Fritze K, Sommer C, Schmitz B, Mies G, Hossmann KA, Kiessling M, Wiessner C, Effect of global system for mobile communication (GSM) microwave exposure on blood-brain barrier permeability in rat. *Acta Neuropathol (Berl)* 94(5):465-470, 1997.

We investigated the effects of global system for mobile communication (GSM) microwave exposure on the permeability of the blood-brain barrier using a calibrated microwave exposure system in the 900 MHz band. Rats were restrained in a carousel of circularly arranged plastic tubes and sham-exposed or microwave irradiated for a duration of 4 h at specific brain absorption rates (SAR) ranging from 0.3 to 7.5 W/kg. The extravasation of proteins was assessed either at the end of exposure or 7 days later in three to five coronal brain slices by immunohistochemical staining of serum albumin. As a positive control two rats were subjected to cold injury. In the brains of freely moving control rats (n = 20) only one spot of extravasated serum albumin could be detected in one animal. In the sham-exposed control group (n = 20) three animals exhibited a total of 4 extravasations. In animals irradiated for 4 h at SAR of 0.3, 1.5 and 7.5 W/kg (n = 20 in each group) five out of the ten animals of each group killed at the end of the exposure showed 7, 6 and 14 extravasations, respectively. In the ten animals of each group killed 7 days after exposure, the total number of extravasations was 2, 0 and 1, respectively. The increase in serum albumin extravasations after microwave exposure reached significance only in the group exposed to the highest SAR of 7.5 W/kg but not at the lower intensities. Histological injury was not observed in any of the examined brains. Compared to other pathological conditions with increased blood-brain barrier permeability such as cold injury, the here observed serum albumin extravasations are very modest and, moreover, reversible. Microwave exposure in the frequency and intensity range of mobile telephony is unlikely to produce pathologically significant changes of the blood-brain barrier permeability.

Furubayashi T, Ushiyama A, Terao Y, Mizuno Y, Shirasawa K, Pongpaibool P, Simba AY, Wake K, Nishikawa M, Miyawaki K, Yasuda A, Uchiyama M, Yamashita HK, Masuda H, Hirota S, Takahashi M, Okano T, Inomata-Terada S, Sokejima S, Maruyama E, Watanabe S, Taki M, Ohkubo C, Ugawa Y. Effects of short-term W-CDMA mobile phone base station exposure on women with or without mobile phone related symptoms. *Bioelectromagnetics*. 30(2):100-113, 2009.

To investigate possible health effects of mobile phone use, we conducted a double-blind, cross-over provocation study to confirm whether subjects with mobile phone related symptoms (MPRS) are more susceptible than control subjects to the effect of electromagnetic fields (EMF) emitted from base stations. We sent questionnaires to 5,000 women and obtained 2,472 valid responses from possible candidates; from these, we recruited 11 subjects with MPRS and 43 controls. There

were four EMF exposure conditions, each of which lasted 30 min: continuous, intermittent, and sham exposure with and without noise. Subjects were exposed to EMF of 2.14 GHz, 10 V/m (W-CDMA), in a shielded room to simulate whole-body exposure to EMF from base stations, although the exposure strength we used was higher than that commonly received from base stations. We measured several psychological and cognitive parameters pre- and post-exposure, and monitored autonomic functions. Subjects were asked to report on their perception of EMF and level of discomfort during the experiment. The MPRS group did not differ from the controls in their ability to detect exposure to EMF; nevertheless they consistently experienced more discomfort, regardless of whether or not they were actually exposed to EMF, and despite the lack of significant changes in their autonomic functions. Thus, the two groups did not differ in their responses to real or sham EMF exposure according to any psychological, cognitive or autonomic assessment. In conclusion, we found no evidence of any causal link between hypersensitivity symptoms and exposure to EMF from base stations.

Gadhia PK, Shah T, Mistry A, Pithawala M, Tamakuwala D. A Preliminary Study to Assess Possible Chromosomal Damage Among Users of Digital Mobile Phones. *Electromag Biol Med* 22:149-159, 2003.

In a preliminary study to examine possible lymphocyte chromosomal damage, we have tested two cytogenetic endpoints, namely, chromosomal aberrations (CA) and sister chromatid exchange frequencies (SCE), in 24 mobile phone users (12 nonsmoker–nonalcoholic subjects and 12 smoker–alcoholics), who used digital mobile phones for at least 2 years, employing Gaussian Minimum Shift Keying modulations with uplink frequencies at 935–960 MHz. and downlinks at 890–915 MHz. For comparison, the control study group included another 24 individuals, matched according to their age, sex, drinking and smoking habits, as well as similar health status, working habits, and professional careers; but did not use mobile phones. Blood samples of 12 mobile users (6 smoker–alcoholic and 6 nonsmoker–nonalcoholic) and 12 controls (identical to mobile users in every respect) were further treated with a known mutagen Mitomycin-C (MMC) to find out comutagenic/synergistic effect. A complete blood picture for each individual was assessed with an automatic particle cell counter.

There was a significant increase ($P < 0.05$) in dicentric chromosomes among mobile users who were smoker–alcoholic as compared to nonsmoker–nonalcoholic; the same held true for controls of both types. After MMC treatment, there was a significant increase in dicentrics ($P < 0.05$) and ring chromosomes ($P < 0.001$) in both smoker–alcoholic and nonsmoker–nonalcoholic mobile users when compared with the controls. Although SCEs showed a significant increase among mobile users, no change in cell cycle progression was noted. The hematological picture showed only minor variations between mobile users and controls.

Galloni P, Lovisolo GA, Mancini S, Parazzini M, Pinto R, Piscitelli M, Ravazzani P, Marino C. Effects of 900 MHz electromagnetic fields exposure on cochlear cells' functionality in rats: Evaluation of distortion product otoacoustic emissions. *Bioelectromagnetics*. 2005a Jul 21; [Epub ahead of print]

In recent years, the widespread use of mobile phones has been accompanied by public debate about possible adverse consequences on human health. The auditory system is a major target of exposure to electromagnetic fields (EMF) emitted by cellular telephones; the aim of this study was the evaluation of possible effects of cellular phone-like emissions on the functionality of rat's cochlea. Distortion Products OtoAcoustic Emission (DPOAE) amplitude was selected as cochlea's outer hair cells (OHC) status indicator. A number of protocols, including different frequencies (the lower ones in rat's cochlea sensitivity spectrum), intensities and periods of exposure, were used; tests were carried out before, during and after the period of treatment. No significant variation due to exposure to microwaves has been evidenced.

Galloni P, Parazzini M, Piscitelli M, Pinto R, Lovisolo GA, Tognola G, Marino C, Ravazzani P. Electromagnetic Fields from Mobile Phones do not Affect the Inner Auditory System of Sprague-Dawley Rats. *Radiat Res*. 164(6):798-804, 2005b.

The auditory system is the first biological structure facing the electromagnetic fields emitted by mobile phones. The aim of this study was to evaluate the cochlear functionality of Sprague-Dawley rats exposed to electromagnetic fields at the typical frequencies of GSM mobile phones (900 and 1800 MHz) by distortion product otoacoustic emissions, which are a well-known indicator of the status of the cochlea's outer hair cells. A population of 48 rats was divided into exposed and sham-exposed groups. Three sets of four loop antennas, one for sham-exposed animals and two for exposed animals, were

used for the local exposures. Rats were exposed 2 h/day, 5 days/week for 4 weeks at a local SAR of 2 W/kg in the ear. Distortion product otoacoustic emissions tests were carried out before, during and after the exposure. The analysis of the data shows no statistically significant differences between the audiological signals recorded for the different groups

Gandhi G, Anita. Genetic damage in mobile phone users: some preliminary findings. *Ind J Hum Genet* 11(2): 99-104, 2005a.

BACKGROUND: The impact of microwave (MW)/radio frequency radiation (RFR) on important biological parameters is probably more than a simply thermal one. Exposure to radio frequency (RF) signals generated by the use of cellular telephones have increased dramatically and reported to affect physiological, neurological, cognitive and behavioural changes and to induce, initiate and promote carcinogenesis. Genotoxicity of RFR has also been reported in various test systems after *in vitro* and/or *in vivo* exposure but none in mobile phone users.

AIMS: In the present study, DNA and chromosomal damage investigations were carried out on the peripheral blood lymphocytes of individuals using mobile phones, being exposed to MW frequency ranging from 800 to 2000 MHz.

METHODS: DNA damage was assessed using the single cell gel electrophoresis assay and aneugenic and clastogenic damage by the *in vivo* capillary blood micronucleus test (MNT) in a total of 24 mobile phone users.

RESULTS: Mean comet tail length (26.76 ± 0.054 mm; 39.75% of cells damaged) in mobile phone users was highly significant from that in the control group. The *in vivo* capillary blood MNT also revealed highly significant (0.25) frequency of micronucleated (MNd) cells.

CONCLUSIONS: These results highlight a correlation between mobile phone use (exposure to RFR) and genetic damage and require interim public health actions in the wake of widespread use of mobile telephony.

Gandhi G, Singh P. Cytogenetic damage in mobile phone users: preliminary data. *Int J Hum Genet* 5(4):259-265, 2005b.

Mobile telephones, sometimes called cellular (cell) phones or handies, are now an integral part of modern life. The mobile phone handsets are low-powered radiofrequency transmitters, emitting maximum powers in the range of 0.2 to 0.6 watts. Scientific concerns have increased sufficiently over the possible hazard to health from using cell phones. The reported adverse health effects include physiological, behavioural and cognitive changes as well as tumour formation and genetic damage. However findings are controversial and no consensus exists. Genotoxicity has been observed either in lower organisms or in vitro studies. The aim of the present study hence was to detect any cytogenetic damage in mobile phone users by analysing short term peripheral lymphocyte cultures for chromosomal aberrations and the buccal mucosal cells for micronuclei (aneugenicity and clastogenicity). The results revealed increased number of micronucleated buccal cells and cytological abnormalities in cultured lymphocytes indicating the genotoxic response from mobile phone use.

Garcia Callejo FJ, Garcia Callejo F, Pena Santamaria J, Alonso Castaneira I, Sebastian Gil E, Marco Algarra J. [Hearing level and intensive use of mobile phones] *Acta Otorrinolaringol Esp.* 56(5):187-191, 2005.

[Article in Spanish]

INTRODUCTION: Wide studies and substantial controversies build on utilization of actual mobile phones and appearance of systemic disorders or even tumours, but there is no knowledge about an eventual involvement on early hearing loss. **PATIENTS AND METHODS:** In a group of three hundred and twenty-three healthy and normoacoustic volunteers who were usual costumers of mobile phones an audiometric evaluation was made at the beginnig of its use and three years later, inquiring about the periods of time per day and year employed on direct contacts with phone. A healthy and normoacoustic control group of non users was studied too. **RESULTS:** Cases carried out 24.3 ± 8.2 active contacts, reaching 50.4 ± 27.8 days of mobile phone employment in three years. Audiometric curve was similar in cases and controls at the beginning of the study. After this follow-up, cases showed an increase on hearing threshold between 1 and 5 dB HL more than controls in speech tones ($p < 0.001$). Moreover, there was a trend to correlate time of phone use to

hearing impairment, but this finding did not result statistically significant. **CONCLUSIONS:** Frequent management of mobile phones in a middle period of time allows to detect a mild hearing loss, but the cause of this disorder keeps unclear.

Gatta L, Pinto R, Ubaldi V, Pace L, Galloni P, Lovisolo GA, Marino C, Pioli C. Effects of In Vivo Exposure to GSM-Modulated 900 MHz Radiation on Mouse Peripheral Lymphocytes. *Radiat Res.* 160(5):600-605, 2003.

The aim of this study was to evaluate whether daily whole-body exposure to 900 MHz GSM-modulated radiation could affect spleen lymphocytes. C57BL/6 mice were exposed 2 h/day for 1, 2 or 4 weeks in a TEM cell to an SAR of 1 or 2 W/kg. Untreated and sham-exposed groups were also examined. At the end of the exposure, mice were killed humanely and spleen cells were collected. The number of spleen cells, the percentages of B and T cells, and the distribution of T-cell subpopulations (CD4 and CD8) were not altered by the exposure. T and B cells were also stimulated ex vivo using specific monoclonal antibodies or LPS to induce cell proliferation, cytokine production and expression of activation markers. The results did not show relevant differences in either T or B lymphocytes from mice exposed to an SAR of 1 or 2 W/kg and sham-exposed mice with few exceptions. After 1 week of exposure to 1 or 2 W/kg, an increase in IFN-gamma (Ifng) production was observed that was not evident when the exposure was prolonged to 2 or 4 weeks. This suggests that the immune system might have adapted to RF radiation as it does with other stressing agents. All together, our in vivo data indicate that the T- and B-cell compartments were not substantially affected by exposure to RF radiation and that a clinically relevant effect of RF radiation on the immune system is unlikely to occur.

Gorlitz BD, Muller M, Ebert S, Hecker H, Kuster N, Dasenbrock C.

Effects of 1-Week and 6-Week Exposure to GSM/DCS Radiofrequency Radiation on Micronucleus Formation in B6C3F1 Mice. *Radiat Res.* 164(4):431-439, 2005.

The aim of this study was to examine the possible induction of micronuclei in erythrocytes of the peripheral blood and bone marrow and in keratinocytes and spleen lymphocytes of mice exposed to radiofrequency (RF) radiation for 2 h per day over periods of 1 and 6 weeks, respectively. The applied signal simulated the exposure from GSM900 and DCS1800 handsets, including the low-frequency amplitude-modulation components as they occur during speaking (GSM Basic), listening (DTX) and moving within the environment (handovers, power control). The carrier frequency was set to the center of the system's uplink band, i.e., 902 MHz for GSM and 1747 MHz for DCS. Uniform whole-body exposure was achieved by restraining the mice in tubes at fixed positions in the exposure setup. Mice were exposed to slot-averaged whole-body SARs of 33.2, 11.0, 3.7 and 0 mW/g during the 1-week study and 24.9, 8.3, 2.8 and 0 mW/g during the 6-week study. Exposure levels for the 1- and 6-week studies were determined in a pretest to confirm that no thermal effect was present that could influence the genotoxic end points. During both experiments and for both frequencies, no clinical abnormalities were detected in the animals. Cells of the bone marrow from the femur (1-week study), erythrocytes of the peripheral blood (6-week study), keratinocytes from the tail root, and lymphocytes from the spleen (both studies) were isolated on slides and stained for micronucleus analysis. Two thousand cells per animal were scored in erythrocyte and keratinocyte samples. In spleen lymphocytes, 1000 binucleated lymphocytes were scored for each animal. The RF-field exposure had no influence on the formation of red blood cells. After 1 week of exposure, the ratio of polychromatic to normochromatic erythrocytes was unchanged in the treated groups compared to the sham-exposed groups. Furthermore, the RF-field exposure of mice did not induce an increase in the number of micronuclei in erythrocytes of the bone marrow or peripheral blood, in keratinocytes, or in spleen lymphocytes compared to the sham-treated control.

Gos P, Eicher B, Kohli J, Heyer WD, No mutagenic or recombinogenic effects of mobile phone fields at 900 MHz detected in the yeast *saccharomyces cerevisiae*. *Bioelectromagnetics* 21(7):515-523, 2000.

Both actively growing and resting cells of the yeast *Saccharomyces cerevisiae* were exposed to 900-MHz fields that closely matched the Global System for Mobile Communication (GSM) pulsed modulation format signals for mobile phones at specific absorption rates (SAR) of 0.13 and 1.3 W/kg. Two identical anechoic test chambers were constructed to perform concurrent control and test experiments under well-controlled exposure conditions. Using specific test strains, we examined the genotoxic potential of mobile phone fields, alone and in combination, with a known genotoxic compound, the alkylating agent methyl

methansulfonate. Mutation rates were monitored by two test systems, a widely used gene-specific forward mutation assay at CAN1 and a wide-range assay measuring the induction of respiration-deficient (petite) clones that have lost their mitochondrial function. In addition, two further assays measured the recombinogenic effect of mobile phone fields to detect possible effects on genomic stability: First, an intrachromosomal, deletion-formation assay previously developed for genotoxic screening; and second, an intragenic recombination assay in the ADE2 gene. Fluctuation tests failed to detect any significant effect of mobile phone fields on forward mutation rates at CAN1, on the frequency of petite formation, on rates of intrachromosomal deletion formation, or on rates of intragenic recombination in the absence or presence of the genotoxic agent methyl methansulfonate.

Goswami PC, Albee LD, Parsian AJ, Baty JD, Moros EG, Pickard WF, Roti Roti JL, Hunt CR, Proto-oncogene mRNA levels and activities of multiple transcription factors in C3H 10T 1/2 murine embryonic fibroblasts exposed to 835.62 and 847.74 MHz cellular phone communication frequency radiation. *Radiat Res* 151(3):300-309, 1999.

This study was designed to determine whether two differently modulated radiofrequencies of the type generally used in cellular phone communications could elicit a general stress response in a biological system. The two modulations and frequencies studied were a frequency-modulated continuous wave (FMCW) with a carrier frequency of 835.62 MHz and a code division multiple-access (CDMA) modulation centered on 847.74 MHz. Changes in proto-oncogene expression, determined by measuring Fos, Jun, and Myc mRNA levels as well as by the DNA-binding activity of the AP1, AP2 and NF-kappaB transcription factors, were used as indicators of a general stress response. The effect of radiofrequency exposure on proto-oncogene expression was assessed (1) in exponentially growing C3H 10T 1/2 mouse embryo fibroblasts during their transition to plateau phase and (2) during transition of serum-deprived cells to the proliferation cycle after serum stimulation. Exposure of serum-deprived cells to 835.62 MHz FMCW or 847.74 MHz CDMA microwaves (at an average specific absorption rate, SAR, of 0.6 W/kg) did not significantly change the kinetics of proto-oncogene expression after serum stimulation. Similarly, these exposures did not affect either the Jun and Myc mRNA levels or the DNA-binding activity of AP1, AP2 and NF-kappaB in exponential cells during transit to plateau-phase growth. Therefore, these results suggest that the radiofrequency exposure is unlikely to elicit a general stress response in cells of this cell line under these conditions. However, statistically significant increases (approximately 2-fold, $P = 0.001$) in Fos mRNA levels were detected in exponential cells in transit to the plateau phase and in plateau-phase cells exposed to 835.62 MHz FMCW microwaves. For 847.74 MHz CDMA exposure, the increase was 1.4-fold ($P = 0.04$). This increase in Fos expression suggests that expression of specific genes could be affected by radiofrequency exposure.

Grafström G, Nittby H, Brun A, Malmgren L, Persson BR, Salford LG, Eberhardt J. Histopathological examinations of rat brains after long-term exposure to GSM-900 mobile phone radiation. *Brain Res Bull.* 2008 Sep 6. [Epub ahead of print]

In order to mimic the real life situation, with often life-long exposure to the electromagnetic fields emitted by mobile phones, we have investigated in a rat model the effects of repeated exposures under a long period to Global System for Mobile Communication-900MHz (GSM-900) radiation. Out of a total of 56 rats, 32 were exposed once weekly in a 2-h period, for totally 55 weeks, at different average whole-body specific absorption rates (SAR) (of in average 0.6 and 60mW/kg at the initiation of the experimental period). The animals were exposed in a transverse electromagnetic transmission line chamber (TEM-cell) to radiation emitted by a GSM-900 test phone. Sixteen animals were sham exposed and eight animals were cage controls, which never left the animal house. After behavioural tests, 5-7 weeks after the last exposure, the brains were evaluated for histopathological alterations such as albumin extravasation, dark neurons, lipofuscin aggregation and signs of cytoskeletal and neuritic neuronal changes of the type seen in human ageing. In this study, no significant alteration of any these histopathological parameters was found, when comparing the GSM exposed animals to the sham exposed controls.

Grigor'ev IuG. [Biological effects of mobile phone electromagnetic field on chick embryo (risk assessment using the mortality rate)] *Radiats Biol Radioecol.* 43(5):541-543, 2003.

[Article in Russian]

Chicken embryos were exposed to EMF from GSM mobile phone during the embryonic development (21 days). As a result the embryo mortality rate in the incubation period increased to 75% (versus 16% in control group).

Grisanti G, Parlapiano C, Tamburello CC, Tine G, Zanforlin L. Cellular phone effects on otoacoustic emissions. *IEEE MTT-S Digest 2: 771-774, 1998.*

A study on bioelectromagnetic effects induced by the use of TACS phones, evidencing a variation of the natural response of the auditory system is presented. This study was performed applying a method based on the registration of the evoked otoacoustic emissions (transient and distortion products). The experimental results show that modulated electromagnetic fields modify the distortion products in about all the examined subjects.

Gul A, Celebi H, Uğraş S. The effects of microwave emitted by cellular phones on ovarian follicles in rats. *Arch Gynecol Obstet. 2009 Feb 25. [Epub ahead of print]*

OBJECTIVE: The aim of this study was to investigate whether there were any toxic effects of microwaves of cellular phones on ovaries in rats. **METHODS:** In this study, 82 female pups of rats, aged 21 days (43 in the study group and 39 in the control group) were used. Pregnant rats in the study group were exposed to mobile phones that were placed beneath the polypropylene cages during the whole period of pregnancy. The cage was free from all kinds of materials, which could affect electromagnetic fields. A mobile phone in a standby position for 11 h and 45 min was turned on to speech position for 15 min every 12 h and the battery was charged continuously. On the 21st day after the delivery, the female rat pups were killed and the right ovaries were removed. The volumes of the ovaries were measured and the number of follicles in every tenth section was counted. **RESULTS:** The analysis revealed that in the study group, the number of follicles was lower than that in the control group. The decreased number of follicles in pups exposed to mobile phone microwaves suggest that intrauterine exposure has toxic effects on ovaries. **CONCLUSION:** We suggest that the microwaves of mobile phones might decrease the number of follicles in rats by several known and, no doubt, countless unknown mechanisms.

Guney M, Ozguner F, Oral B, Karahan N, Mungan T. 900 MHz radiofrequency-induced histopathologic changes and oxidative stress in rat endometrium: protection by vitamins E and C. *Toxicol Ind Health. 23(7):411-420, 2007.*

There are numerous reports on the effects of electromagnetic radiation (EMR) in various cellular systems. Mechanisms of adverse effects of EMR indicate that reactive oxygen species (ROS) may play a role in the biological effects of this radiation. The aims of this study were to examine 900 MHz mobile phone-induced oxidative stress that promotes production of ROS and to investigate the role of vitamins E and C, which have antioxidant properties, on endometrial tissue against possible 900 MHz mobile phone-induced endometrial impairment in rats. The animals were randomly grouped (eight each) as follows: 1) Control group (without stress and EMR, Group I), 2) sham-operated rats stayed without exposure to EMR (exposure device off, Group II), 3) rats exposed to 900 MHz EMR (EMR group, Group III) and 4) a 900 MHz EMR exposed + vitamin-treated group (EMR + Vit group, Group IV). A 900 MHz EMR was applied to EMR and EMR + Vit group 30 min/day, for 30 days using an experimental exposure device. Endometrial levels of nitric oxide (NO, an oxidant product) and malondialdehyde (MDA, an index of lipid peroxidation), increased in EMR exposed rats while the combined vitamins E and C caused a significant reduction in the levels of NO and MDA. Likewise, endometrial superoxide dismutase (SOD), catalase (CAT) and glutathione peroxidase (GSH-Px) activities decreased in EMR exposed animals while vitamins E and C caused a significant increase in the activities of these antioxidant enzymes. In the EMR group histopathologic changes in endometrium, diffuse and severe apoptosis was present in the endometrial surface epithelial and glandular cells and the stromal cells. Diffuse eosinophilic leucocyte and lymphocyte infiltration were observed in the endometrial stroma whereas the combination of vitamins E and C caused a significant decrease in these effects of EMR. It is concluded that oxidative endometrial damage plays an important role in the 900 MHz mobile phone-induced endometrial impairment and the modulation of oxidative stress with vitamins E and C reduces the 900 MHz mobile phone-induced endometrial damage both at biochemical and histological levels.

Haarala C, Bjornberg L, Ek M, Laine M, Revonsuo A, Koivisto M, Hamalainen H. Effect of a 902 MHz electromagnetic field emitted by mobile phones on human cognitive function: A replication study. *Bioelectromagnetics 24(4):283-288, 2003a.*

Our study was a replication and extension with methodological improvements to a previous study on effects of the

electromagnetic field (EMF) emitted by a 902 MHz mobile phone on human cognitive functioning. Improvements on the previous study included multicentre testing and a double blind design. A total of 64 subjects (32 men and 32 women) in two independent laboratories performed a battery of 9 cognitive tasks twice: while the EMF was on and while it was off. Reaction times (RTs) and accuracy were recorded. The order of exposure and tasks was counterbalanced across subjects and gender. There were no statistically significant differences in performance between genders or laboratories. Although the RTs and the accuracy of answers were very similar to those of our previous study, our previous results were not replicated. We concluded that EMF had no effect on RTs or on the accuracy of the subjects' answers. Further, our results indicate that our EMF had no immediate effect on human cognitive functioning or that such effects are so small that they are observed on behavior only occasionally.

Haarala C, Aalto S, Hautzel H, Julkunen L, Rinne JO, Laine M, Krause B, Hamalainen H. Effects of a 902 MHz mobile phone on cerebral blood flow in humans: a PET study. *Neuroreport*. 14(16):2019-2023, 2003b.

SUMMARY: Fourteen healthy right-handed subjects were scanned using PET with a [¹⁵O]water tracer during exposure to electromagnetic field (EMF) emitted by a mobile phone and a sham-exposure under double-blind conditions. During scanning, the subjects performed a visual working memory task. Exposure to an active mobile phone produced a relative decrease in regional cerebral blood flow (rCBF) bilaterally in the auditory cortex but no rCBF changes were observed in the area of maximum EMF. It is possible that these remote findings were caused by the EMF emitted by the active mobile phone. A more likely interpretation of the present findings were a result of an auditory signal from the active mobile phone. Therefore, it is not reasoned to attribute this finding to the EMF emitted by the phone. Further study on human rCBF during exposure to EMF of a mobile phone is needed.

Haarala C, Ek M, Bjornberg L, Laine M, Revonsuo A, Koivisto M, Hamalainen H. 902 MHz mobile phone does not affect short term memory in humans. *Bioelectromagnetics*. 25(6):452-456, 2004.

We studied the effects of an electromagnetic field (EMF) as emitted by a 902 MHz mobile phone on human short term memory. This study was a replication with methodological improvements to our previous study. The improvements included multi-centre testing and a double blind design. A total of 64 subjects (32 men) in two independent laboratories performed a short term memory task (n-back) which poses a varying memory load (0-3 items) on the subjects' memory. They performed the task twice, once each under EMF and sham exposure. Reaction times (RTs) and accuracy of the responses were recorded. The order of exposure and memory load conditions were counterbalanced across subjects and gender. There were no statistically significant differences in performance between the two laboratories. We could not replicate our previous results: the EMF had no effect on RTs or on the accuracy of the subjects' answers. The inability to replicate previous findings could have been caused by lack of actual EMF effects or the magnitude of effects being at the sensitivity threshold of the test used.

Haarala C, Bergman M, Laine M, Revonsuo A, Koivisto M, Hamalainen H.
Electromagnetic field emitted by 902 MHz mobile phones shows no effects on children's cognitive function. *Bioelectromagnetics*. 2005 Jul 29; [Epub ahead of print]

The present study investigated the potential effects of a standard 902 MHz global system for mobile communication (GSM) mobile phone on 10-14 years old children's cognitive function. A total of 32 children (16 boys, 16 girls) participated with their own and parental consent. The subjects were 10-14 years old (mean 12.1 years, SD 1.1). They performed a battery of cognitive tests twice in a counter-balanced order: once while exposed to an active mobile phone and once during exposure to an inactive phone. The tests were selected from those we used earlier with adults. The statistical analyses showed no significant differences between the mobile phone off and on conditions in reaction times and accuracy over all tests or in any single test. It was concluded that a standard mobile phone has no effect on children's cognitive function as measured by response speed and accuracy. The present results challenge some earlier findings suggesting that the electromagnetic field (EMF) created by an active mobile phone would facilitate cognitive functioning.

Haarala C, Takio F, Rintee T, Laine M, Koivisto M, Revonsuo A, Hamalainen H. Pulsed and continuous wave mobile phone exposure over left versus right hemisphere: Effects on human cognitive function. *Bioelectromagnetics*. 2007 Jan 3; [Epub ahead of print]

The possible effects of continuous wave (CW) and pulse modulated (PM) electromagnetic field (EMF) on human cognition was studied in 36 healthy male subjects. They performed cognitive tasks while exposed to CW, PM, and sham EMF. The subjects performed the same tasks twice during each session; once with left-sided and once with right-sided exposure. The EMF conditions were spread across three testing sessions, each session separated by 1 week. The exposed hemisphere, EMF condition, and test order were counterbalanced over all subjects. We employed a double-blind design: both the subject and the experimenter were unaware of the EMF condition. The EMF was created with a signal generator connected via amplifier to a dummy phone antenna, creating a power output distribution similar to the original commercial mobile phone. The EMF had either a continuous power output of 0.25 W (CW) or pulsed power output with a mean of 0.25 W. An additional control group of 16 healthy male volunteers performed the same tasks without any exposure equipment to see if mere presence of the equipment could have affected the subjects' performance. No effects were found between the different EMF conditions, separate hemisphere exposures, or between the control and experimental group. In conclusion, the current results indicate that normal mobile phones have no discernible effect on human cognitive function as measured by behavioral tests.

Hamblin DL, Wood AW, Croft RJ, Stough C. Examining the effects of electromagnetic fields emitted by GSM mobile phones on human event-related potentials and performance during an auditory task. *Clin Neurophysiol*. 115(1):171-178, 2004.

OBJECTIVE: Due to the widespread use of mobile phones (MP), it is important to determine whether they affect human physiology. The aim of this study was to explore the sensitivity of auditory event-related potentials to electromagnetic emissions. **METHODS:** Twelve participants attended two sessions, 1 week apart. Participants performed an auditory oddball task while they were exposed to an active MP during one session and sham exposure during the other. Each condition lasted 1 h and order was counterbalanced. N100 and P200 latencies and amplitudes were analysed for non-target waveforms, and N200 and P300 latencies and amplitudes were analysed for target waveforms. **RESULTS:** In real relative to sham exposure N100 amplitude and latency to non-targets were reduced, with the reduction larger over midline and right hemisphere sites. P300 latency to targets was delayed in the real exposure condition, however as this difference was greatest at left frontal and left central sites the interpretation of this result is unclear. Reaction time increased in the real relative to sham condition. No difference in accuracy was found. **CONCLUSIONS:** The results suggest that MP exposure may affect neural activity, particularly in proximity to the phone, however caution should be applied due to the small sample size.

Hamblin DL, Croft RJ, Wood AW, Stough C, Spong J. The sensitivity of human event-related potentials and reaction time to mobile phone emitted electromagnetic fields. *Bioelectromagnetics*. 2006 Jan 25; [Epub ahead of print]

There is some evidence to suggest that exposure to mobile phones (MPs) can affect neural activity, particularly in response to auditory stimuli. The current investigation (n = 120) aimed to test recent findings in this area, namely that N100 amplitude and latency would decrease, and that P300 latency and reaction time (RT) would increase under active relative to sham exposure during an auditory task. Visual measures were also explored. A double blind, counterbalanced, crossover design was employed where subjects attended two sessions 1 week apart. In both sessions participants (1) performed auditory and visual oddball tasks while electroencephalogram (EEG) was recorded with a MP set to sham exposure mounted over the temporal region, and (2) performed the same tasks while the handset was set to active/sham. When active, the MP transmitted for 30 min at 895 MHz (average power 250 mW, pulse modulated at 217 Hz, average SAR 0.11 W/kg). Paired t-tests compared difference scores from the sham/sham session to those from the sham/active condition. The study was designed to detect differences of $\frac{1}{4}$ of a standard deviation with a power of 0.80. There was no significant difference between exposure conditions for any auditory or visual event related potential (ERP) component or RT. As previous positive findings were not replicated, it was concluded that there is currently no evidence that acute MP exposure affects these indices of brain activity

Hardell L, Hansson Mild K, Pahlson A, Hallquist A, Ionizing radiation, cellular telephones and the risk of brain tumours. *Europ J Cancer Prevent* 10:523-529, 2001.

A case-control study on brain tumours included 233 patients aged 20-80 years and alive at the study time. They had histopathologically verified brain tumour and lived in the Uppsala-Orebro region (1994-1996) or in Stockholm region (1995-1996). Two matched controls to each case were selected from the Swedish Population Register. Two hundred and nine cases (90%) and 425 controls (91%) answered the questionnaire. Results are presented for the whole study group, as given here, and for malignant and benign tumours separately. For workers in the chemical industry the odds ratio (OR) was 4.10, 95% confidence interval (95% CI) 1.25-13.4 and laboratory workers OR 3.21, 95% CI 1.16-8.85. Radiotherapy of the head and neck region gave OR 3.61, 95% CI 0.65-19.9. Medical diagnostic X-ray of the same area yielded OR 1.64, 95% CI 1.04-2.58. Work as a physician gave OR 6.00, 95% CI 0.62-57.7. All three cases had worked with fluoroscopy. Ipsilateral (same side) use of a cellular telephone increased the risk of tumours in the temporal, temporo-parietal and occipital areas, with OR 2.42, 95% CI 0.97-6.05 (i.e., the anatomical areas with highest exposure to microwaves from a mobile phone).

Hardell, L, Nasman, A, Pahlson, A, Hallquist, A, Hansson Mild, K, Use of cellular telephones and the risk for brain tumours: A case-control study. *Int J Oncol* 15(1):113-116, 1999.

The use of cellular telephones has increased dramatically during the 1990's in the world. In the 1980's the analogue NMT system was used whereas the digital GSM system was introduced in early 1990's and is now the preferred system. Case reports of brain tumours in users initiated this case-control study on brain tumours and use of cellular telephones. Also other exposures were assessed. All cases, both males and females, with histopathologically verified brain tumour living in Uppsala-Orebro region (1994-96) and Stockholm region (1995-96) aged 20-80 at the time of diagnosis and alive at start of the study were included, 233 in total. Two controls to each case were selected from the Swedish Population Register matched for sex, age and study region. Exposure was assessed by questionnaires supplemented over the phone. The analyses were based on answers from 209 (90%) cases and 425 (91%) controls. Use of cellular telephone gave odds ratio (OR) = 0.98 with 95% confidence interval (CI) = 0.69-1.41. For the digital GSM system OR = 0.97, CI = 0.61-1.56 and for the analogue NMT system OR = 0.94, CI = 0.62-1.44 were calculated. Dose-response analysis and using different tumour induction periods gave similar results. Non-significantly increased risk was found for tumour in the temporal or occipital lobe on the same side as a cellular phone had been used, right side OR = 2.45, CI = 0.78-7.76, left side OR = 2.40, CI = 0.52-10.9 Increased risk was found only for use of the NMT system. For GSM use the observation time is still too short for definite conclusions. An increased risk for brain tumour in the anatomical area close to the use of a cellular telephone should be especially studied in the future.

Hardell L, Nasman A, Pahlson A, Hallquist A, Case-Control Study on Radiology Work, Medical X-ray Investigations, and Use of Cellular Telephones as Risk Factors for Brain Tumors. *Medscape General Medicine* May 4, 2000.

Abstract

Context. Ionizing radiation is a well-established risk factor for brain tumors. During recent years, microwave exposure from the use of cellular telephones has been discussed as a potential risk factor.

Objective. To determine risk factors for brain tumors.

Design. A case-control study, with exposure assessed by questionnaires.

Participants. A total of 233 currently living men and women, aged 20 to 80 years, were included. The case patients had histopathologically verified brain tumors and lived in the Uppsala-Orebro region (1994-1996) or the Stockholm region (1995-1996). Two matched controls to each case were selected from the Swedish Population Register.

Main Outcome Measures. Ionizing radiation and use of cellular telephones as risk factors for brain tumors.

Results. A total of 209 cases (90%) and 425 controls (91%) answered the questionnaire. Work as a physician yielded an odds ratio (OR) of 6.00, with a 95% confidence interval (CI) of 0.62 to 57.7. All three case patients had worked with fluoroscopy. Radiotherapy of the head and neck region yielded an OR of 3.61 (95% CI, 0.65-19.9). Medical diagnostic x-ray examination of the same area yielded an OR of 2.10 (95% CI, 1.25-3.53), with a tumor induction period of 5 years or more. Chemical industry work yielded an OR of 4.10 (95% CI, 1.25-13.4), and laboratory work yielded an OR of 3.21 (95% CI, 1.16-8.85). Ipsilateral use of cellular telephones increased the risk for tumors in the temporal, temporo-parietal, and occipital lobes (OR, 2.42; 95% CI, 0.97-6.05), ie, the anatomic areas with highest exposure to microwaves from a mobile telephone. The result was further strengthened (OR, 2.62; 95% CI, 1.02-6.71) in a multivariate analysis that included laboratory work and medical diagnostic x-ray investigations of the head and neck.

Conclusion. Exposure to ionizing radiation, work in laboratories, and work in the chemical industry increased the risk of brain tumors. Use of a cellular telephone was associated with an increased risk in the anatomic area with highest exposure.

Hardell L, Hallquist A, Hansson Mild K, Carlberg M, Pahlson A, Lilja A. cellular and cordless telephones and the risk for brain tumours. *Europ J Cancer Prevent* 11:377-386, 2002.

Microwave exposure from the use of cellular telephones has been discussed in recent years as a potential risk factor for brain tumours. We included in a case-control study 1617 patients aged 20-80 years of both sexes with brain tumour diagnosed between 1 January 1997 and 30 June 2000. They were alive at the study time and had histopathologically verified brain tumour. One matched control to each case was selected from the Swedish Population Register. The study area was the Uppsala-Orebro, Stockholm, Linköping and Göteborg medical regions of Sweden. Exposure was assessed by a questionnaire that was answered by 1429 (88%) cases and 1470 (91%) controls. In total, use of analogue cellular telephones gave an increased risk with an odds ratio (OR) of 1.3 (95% confidence interval (CI) 1.02-1.6). With a tumour induction period of >10 years the risk increased further; OR 1.8 (95% CI 1.1-2.9). No clear association was found for digital or cordless telephones. With regard to the anatomical area of the tumour and exposure to microwaves, the risk was increased for tumours located in the temporal area on the same side of the brain that was used during phone calls; for analogue cellular telephones the OR was 2.5 (95% CI 1.3-4.9). Use of a telephone on the opposite side of the brain was not associated with an increased risk for brain tumours. With regard to different tumour types, the highest risk was for acoustic neurinoma (OR 3.5, 95% CI 1.8-6.8) among analogue cellular telephone users.

Hardell L, Mild KH, Carlberg M. Case-control study on the use of cellular and cordless phones and the risk for malignant brain tumours. *Int. J. Radiat. Biol.* 78:931-936, 2002.

Purpose: To investigate the use of cellular and cordless phones and the risk for malignant brain tumours.

Materials and Methods: A case-control study was performed on 649 patients aged 20-80 years of both sexes with malignant brain tumour diagnosed from 1 January 1997 to 30 June 2000. All patients were alive during the time of the study and had histopathology verified brain tumours. One matched control to each case was selected from the Swedish Population Register. The study area was the Uppsala-Orebro, Stockholm, Linköping and Göteborg medical regions of Sweden.

Results: Exposure was assessed by a questionnaire answered by 588 (91%) cases and 581 (90%) controls. Phone usage was defined as 'ever use' and usage starting 1 year before diagnosis was disregarded. Overall, no significantly increased risks were found: analogue cellular phones yielded an odds ratio (OR) = 1.13, 95% confidence interval (CI) = 0.82-1.57, digital cellular phones OR = 1.13, CI = 0.86-1.48, and cordless phones OR = 1.13, CI = 0.85-1.50. For ipsilateral (same side) radiofrequency exposure, analogue mobile phones gave OR = 1.85, CI = 1.16-2.96, for all malignant brain tumours. For astrocytoma, this risk was OR = 1.95, CI = 1.12-3.39. For all malignant brain tumours, digital mobile phones yielded OR = 1.59, CI = 1.05-2.41, and cordless phones yielded OR = 1.46, CI = 0.96-2.23, in the analysis of ipsilateral exposure. Conclusion: The ipsilateral use of an analogue cellular phone yielded a significantly increased risk for malignant brain tumours.

Hardell L, Mild KH, Carlberg M. Further aspects on cellular and cordless telephones and brain tumours. *Int J Oncol* 22(2):399-407, 2003.

We included in a case-control study on brain tumours and mobile and cordless telephones 1,617 patients aged 20-80 years of both sexes diagnosed during January 1, 1997 to June 30, 2000. They were alive at the study time and had histopathology verified brain tumour. One matched control to each case was selected from the Swedish Population Register. The study area was the Uppsala-Orebro, Stockholm, Linköping and Göteborg medical regions of Sweden. Exposure was assessed by a questionnaire that was answered by 1,429 (88%) cases and 1,470 (91%) controls. In total use of analogue cellular telephones gave an increased risk with odds ratio (OR)=1.3, 95% confidence interval (CI)=1.04-1.6, whereas digital and cordless phones did not overall increase the risk significantly. Ipsilateral use of analogue phones gave OR=1.7, 95% CI=1.2-2.3, digital phones OR=1.3, 95% CI=1.02-1.8 and cordless phones OR=1.2, 95% CI=0.9-1.6. The risk for ipsilateral use was significantly increased for astrocytoma for all studied phone types, analogue phones OR=1.8, 95% CI=1.1-3.2, digital phones OR=1.8, 95% CI=1.1-2.8, cordless phones OR=1.8, 95% CI=1.1-2.9. Use of a telephone on the opposite side of the brain was not associated with a significantly increased risk for brain tumours. Regarding anatomical area of the tumour and exposure to microwaves, the risk was increased for tumours located in the

temporal area on the same side of the brain that was used during phone calls, significantly so for analogue cellular telephones OR=2.3, 95% CI=1.2-4.1. For acoustic neurinoma OR=4.4, 95% CI=2.1-9.2 was calculated among analogue cellular telephone users. When duration of use was analysed as a continuous variable in the total material, the risk increased per year for analogue phones with OR=1.04, 95% CI=1.01-1.08. For astrocytoma and ipsilateral use the trend was for analogue phones OR=1.10, 95% CI=1.02-1.19, digital phones OR=1.11, 95% CI=1.01-1.22, and cordless phones OR=1.09, 95% CI=1.01-1.19. There was a tendency of a shorter tumour induction period for ipsilateral exposure to microwaves than for contralateral, which may indicate a tumour promotor effect.

Hardell L, Mild KH, Sandstrom M, Carlberg M, Hallquist A, Pahlson A. Vestibular schwannoma, tinnitus and cellular telephones. *Neuroepidemiol* 22:124-129, 2003.

Cases with tinnitus after using analogue cellular telephones are presented. An increased odds ratio of 3.45, 95% confidence interval (CI) 1.77-6.76, was found for vestibular schwannoma (VS) associated with the use of analogue cell phones. During the time period 1960-1998, the age-standardized incidence of VS in Sweden significantly increased yearly by +2.53% (CI 1.71-3.35). A significant increase in the incidence of VS was only found for the latter of the two time period 1960-1979 and 1980-1998. For all other brain tumors taken together, the incidence significantly increased yearly by +0.80% (CI 0.59-1.02) for the time period 1960-1998, although the increase was only significant for benign tumors other than VS during 1960-1979.

Hardell L, Hallquist A, Hansson Mild K, Carlberg M, Gertzen H, Schildt EB, Dahlqvist A. No association between the use of cellular or cordless telephones and salivary gland tumours. *Occup Environ Med*. 61(8):675-679, 2004.

AIM: To investigate the association between the use of cellular or cordless telephones and the risk for salivary gland tumours. METHODS: Cases were assessed from the six regional cancer registries in Sweden. Four controls matched for sex and age in five year age groups were selected for each case. A total of 293 living cases and 1172 controls were included. RESULTS: There were 267 (91%) participating cases and 1053 (90%) controls. Overall no significantly increased risk was found. Odds ratios were 0.92 (95% CI 0.58 to 1.44) for use of analogue phones, 1.01 (95% CI 0.68 to 1.50) for use of digital phones, and 0.99 (95% CI 0.68 to 1.43) for use of cordless phones. Similar results were found for different salivary gland localisations. No effect of tumour induction period or latency was seen, although few subjects reported use for more than 10 years. CONCLUSIONS: No association between the use of cellular or cordless phones and salivary gland tumours was found, although this study does not permit conclusions for long term heavy use.

Hardell L, Carlberg M, Hansson Mild K. Use of cellular telephones and brain tumour risk in urban and rural areas. *Occup Environ Med* 62:390-394, 2005a.

Aim: To investigate the association between the use of cellular or cordless telephones and the risk for brain tumours in different geographical areas, urban and rural.
Methods: patients aged 20-80 years, living in the middle part of Sweden, and diagnosed between 1 January 1997 and 30 June 2000 were included. One control matched for sex and age in five year age groups was selected for each case. Use of different phone types was assessed by a questionnaire.
Results: The number of participating cases was 1429; there were 1470 controls. An effect of rural living was most pronounced for digital cellular telephones. Living in rural areas yielded an odd ratio (OR) of 1.4 (95% CI 0.98 to 2.0), increasing to 3.2 (95% CI 1.2 to 8.4) with > 5 year latency time for digital phones. The corresponding ORs for living in urban areas were 0.9 (95% CI 0.8 to 1.2) and 0.9 (95% CI 0.6 to 1.4), respectively. This effect was most obvious for malignant brain tumours.
Conclusion: In future studies, place of residence should be considered in assessment of exposure to microwaves from cellular telephone, although the results in this study must be interpreted with caution due to low numbers in some of the calculations.

Hardell L, Carlberg M, Hansson Mild K. Case-Control Study on Cellular and Cordless Telephones and the Risk for Acoustic Neuroma or Meningioma in Patients Diagnosed 2000-2003. *Neuroepidemiology* 25:120-128, 2005b.

We performed a case-control study on the use of cellular and cordless telephones and the risk for brain tumors. We report the results for benign brain tumors with data from 413 cases (89% response rate), 305 with meningioma, 84 with acoustic

neuroma, 24 with other types and 692 controls (84% response rate). For meningioma, analogue phones yielded odds ratio (OR) = 1.7, 95% confidence interval (CI) = 0.97-3.0, increasing to OR = 2.1, 95% CI = 1.1-4.3 with a >10-year latency period. Also digital cellular phones and cordless phones increased the risk to some extent. For acoustic neuroma, analogue phones gave OR = 4.2, 95% CI = 1.8-10 increasing to OR = 8.4, 95% CI = 1.6-45 with a >15-year latency period, but based on low numbers. Digital phones yielded OR = 2.0, 95% CI = 1.05-3.8, whereas for cordless phones OR was not significantly increased. In the multivariate analysis, analogue phones represented a significant risk factor for acoustic neuroma.

Hardell L, Eriksson M, Carlberg M, Sundstrom C, Mild KH. Use of cellular or cordless telephones and the risk for non-Hodgkin's lymphoma. *Int Arch Occup Environ Health*. 2005c Jul 5;1-8 [Epub ahead of print]

Objectives: To evaluate the use of cellular and cordless telephones as the risk factor for non-Hodgkin's lymphoma (NHL). Methods: Male and female subjects aged 18-74 years living in Sweden were included during a period from 1 December 1999 to 30 April 2002. Controls were selected from the national population registry. Exposure to different agents was assessed by questionnaire. Results: In total, 910 (91%) cases and 1016 (92%) controls participated. NHL of the B-cell type was not associated with the use of cellular or cordless telephones. Regarding T-cell NHL and >5 year latency period, the use of analogue cellular phones yielded: odds ratio (OR) = 1.46, 95%; confidence interval (CI) = 0.58-3.70, digital: OR=1.92, 95%; CI=0.77-4.80 and cordless phones: OR=2.47; CI=1.09-5.60. The corresponding results for certain, e.g. cutaneous and leukaemia, T-cell lymphoma for analogue phones were: OR=3.41, 95%; CI=0.78-15.0, digital: OR=6.12, 95%; CI=1.26-29.7 and cordless phones: OR=5.48, 95%; CI=1.26-23.9. Conclusions: The results indicate an association between T-cell NHL and the use of cellular and cordless telephones, however based on low numbers and must be interpreted with caution. Regarding B-cell NHL no association was found.

Hardell, L., Carlberg, M., Mild, K., Case-control study of the association between the use of cellular and cordless telephones and malignant brain tumors diagnosed during 2000-2003. *Environmental Research*. 100: 232-241, 2006a.

We performed a case-control study on the use of cellular and cordless telephones and the risk for brain tumors diagnosed during 2000-2003. We report the results for malignant brain tumors with data from 317 cases (88%) and 692 controls (84%). The use of analog cellular phones yielded odds ratio (OR) of 2.6 and a 95% confidence interval (CI) of 1.5-4.3, increasing to OR=3.5 and 95% CI=2.0-6.4 with a >10-year latency period. Regarding digital cellular telephones, the corresponding results were OR=1.9, 95% CI=1.3-2.7 and OR=3.6, 95% CI=1.7-7.5, respectively. Cordless telephones yielded OR=2.1, 95% CI=1.4-3.0, and with a >10-year latency period, OR=2.9, 95% CI=1.6-5.2. The OR increased with the cumulative number of hours of use and was highest for high-grade astrocytoma. A somewhat increased risk was also found for low-grade astrocytoma and other types of malignant brain tumors, although not significantly so. In multivariate analysis, all three phone types studied showed an increased risk.

Hardell L, Carlberg M, Hansson Mild K. Pooled analysis of two case-control studies on the use of cellular and cordless telephones and the risk of benign brain tumours diagnosed during 1997-2003. *Int J Oncol*. 28(2):509-518, 2006b.

The use of cellular and cordless telephones and the risk of brain tumours is of concern since the brain is a high exposure area. We present the results of a pooled analysis of two case-control studies on benign brain tumours diagnosed during 1997-2003 including answers from 1,254 (88%) cases and 2,162 (89%) controls aged 20-80 years. For acoustic neuroma, the use of analogue cellular phones gave an odds ratio (OR) of 2.9 and a 95% confidence interval (CI) of 2.0-4.3; for digital cellular phones, OR=1.5; 95% CI=1.1-2.1; and for cordless telephones, OR=1.5, 95% CI=1.04-2.0. The highest OR was found for analogue phones with a latency period of >15 years; OR=3.8, 95% CI=1.4-10. Regarding meningioma, the results were as follows: for analogue phones, OR=1.3, 95% CI=0.99-1.7; for digital phones, OR=1.1, 95% CI=0.9-1.3; and for cordless phones, OR=1.1, 95% CI=0.9-1.4. In the multivariate analysis, a significantly increased risk of acoustic neuroma was found with the use of analogue phones.

Hardell L, Carlberg M, Ohlson CG, Westberg H, Eriksson M, Hansson Mild K. Use of cellular and cordless telephones and risk of testicular cancer. *Int J Androl*. 2006 Dec 20; [Epub ahead of print]

A case-control study on testicular cancer included use of cellular and cordless telephones. The results were based on answers from 542 (92%) cases with seminoma, 346 (89%) with non-seminoma, and 870 (89%) controls. Regarding seminoma the use of analog cellular phones gave odds ratio (OR) = 1.2, 95% confidence interval (CI) = 0.9-1.6, digital phones OR = 1.3, CI = 0.9-1.8, and cordless phones OR = 1.1, CI = 0.8-1.5. The corresponding results for non-seminoma were OR = 0.7, CI = 0.5-1.1, OR = 0.9, CI = 0.6-1.4, and OR = 1.0, CI = 0.7-1.4, respectively. There was no dose-response effect and OR did not increase with latency time. No association was found with place of keeping the mobile phone during standby, such as trousers pocket. Cryptorchidism was associated both with seminoma (OR = 4.2, CI = 2.7-6.5) and non-seminoma (OR = 3.3, CI = 2.0-5.6), but no interaction was found with the use of cellular or cordless telephones.

Hardell LO, Carlberg M, Soderqvist F, Hansson Mild K, Morgan LL. Long-term use of cellular phones and brain tumours - increased risk associated with use for > 10 years. *Occup Environ Med.* 2007 Apr 4; [Epub ahead of print]

AIM: To evaluate brain tumour risk among long-term users of cellular telephones. METHODS: One cohort study and 13 case-control studies were identified on this topic. Data were scrutinized for use of mobile phone for > 10 years and ipsilateral exposure if presented. RESULTS: The cohort study was of limit value due to methodological shortcomings in the study. Of the 13 case-control studies, 9 gave results for > 10 years use or latency period. Most of these results were based on low numbers. Clearly an association with acoustic neuroma was found in four studies with two- to three-fold increased risk in the group with at least 10 years use of a mobile phone. No risk was found in one study, but the tumour size was significantly larger among users. Five studies gave results for malignant brain tumours in that latency group. All gave increased OR especially for ipsilateral exposure. Highest OR = 5.4, 95 % CI = 3.0-9.6 was calculated for high-grade glioma and ipsilateral exposure in one study. CONCLUSIONS: Results from present studies on use of mobile phones for > 10 years give a consistent pattern of an increased risk for acoustic neuroma and glioma, most pronounced for high-grade glioma. The risk is highest for ipsilateral exposure.

Hardell L, Carlberg M, Söderqvist E, Hansson Mild K. Meta-analysis of long-term mobile phone use and the association with brain tumours. *Int J Oncol.* 32(5):1097-1103, 2008.

We evaluated long-term use of mobile phones and the risk for brain tumours in case-control studies published so far on this issue. We identified ten studies on glioma and meta-analysis yielded OR = 0.9, 95% CI = 0.8-1.1. Latency period of ≥ 10 -years gave OR = 1.2, 95% CI = 0.8-1.9 based on six studies, for ipsilateral use (same side as tumour) OR = 2.0, 95% CI = 1.2-3.4 (four studies), but contralateral use did not increase the risk significantly, OR = 1.1, 95% CI = 0.6-2.0. Meta-analysis of nine studies on acoustic neuroma gave OR = 0.9, 95% CI = 0.7-1.1 increasing to OR = 1.3, 95% CI = 0.6-2.8 using ≥ 10 -years latency period (four studies). Ipsilateral use gave OR = 2.4, 95% CI = 1.1-5.3 and contra-lateral OR = 1.2, 95% CI = 0.7-2.2 in the ≥ 10 -years latency period group (three studies). Seven studies gave results for meningioma yielding overall OR = 0.8, 95% CI = 0.7-0.99. Using ≥ 10 -years latency period OR = 1.3, 95% CI = 0.9-1.8 was calculated (four studies) increasing to OR = 1.7, 95% CI = 0.99-3.1 for ipsilateral use and OR = 1.0, 95% CI = 0.3-3.1 for contralateral use (two studies). We conclude that this meta-analysis gave a consistent pattern of an association between mobile phone use and ipsilateral glioma and acoustic neuroma using ≥ 10 -years latency period.

Hartikka H, Heinävaara S, Mäntylä R, Kähärä V, Kurtio P, Auvinen A. Mobile phone use and location of glioma: A case-case analysis. *Bioelectromagnetics.* 2009 Jan 13. [Epub ahead of print]

We assessed a new approach for evaluating the glioma risk among users of mobile phones to focus on the part of the brain most heavily exposed to radiofrequency electromagnetic fields from mobile phones. The tumor midpoint was defined from radiological imaging. A case-case analysis with 99 gliomas was performed using logistic regression. The exposed cases were those with the tumor mid-point within 4.6 cm from the line between the mouth and the external meatus of the ear, representing the most likely location of the mobile phone (the source of exposure). Alternative analyses based on various indicators of mobile phone use as the outcome were also carried out. The majority of cases were regular mobile phone users. A slightly higher proportion of gliomas among mobile phone users than non-users occurred within 4.6 cm from the presumed location of the mobile phone (28% vs. 14%). Modestly elevated odds ratios were observed for several indicators of mobile phone use, but without an exposure gradient. The highest odds ratios were found for contralateral and short-term use. Our results, though limited by the small sample size, demonstrate that detailed information on tumor location allows evaluation of the risk related to the most heavily exposed part of the brain, representing direct evaluation

of the possible local carcinogenic effects of the radiofrequency fields. However, field strength varies between users and over time also within a given anatomic site, due to the output power of the phone. Collaborative analysis of a larger sample is planned.

Harvey C, French PW, Effects on protein kinase C and gene expression in a human mast cell line, HMC-1, following microwave exposure. *Cell Biol Int* 23(11):739-748, 2000.

We used a resonant cavity which delivered a continuous wave exposure at 864.3 MHz at an average specific absorption rate (SAR) of 7 W/kg to determine non-thermal biological effects of microwave exposure. A human mast cell line, HMC-1, was used as the biological target. Cells were given three exposures each of 20-min duration daily for 7 days. The temperature of the cell culture medium during the exposure fell to 26.5 degrees C. Effects were seen on localization of protein kinase C, and expression of three genes of 588 screened. The affected genes included the proto-oncogene c-kit, the transcription factor Nucleoside diphosphate kinase B and the apoptosis-associated gene DAD-1. Stress response genes were variably upregulated. No significant effect on morphology or on F-actin distribution was detected. We conclude that low-power microwave exposure may act on HMC-1 cells by altering gene expression via a mechanism involving activation of protein kinase C, and at temperatures well below those known to induce a heat shock response.

Hata K, Yamaguchi H, Tsurita G, Watanabe S, Wake K, Taki M, Ueno S, Nagawa H. Short term exposure to 1439 MHz pulsed TDMA field does not alter melatonin synthesis in rats. *Bioelectromagnetics*. 26(1):49-53, 2005.

The widespread use of the mobile phone has initiated many studies on the possible adverse effects of a high frequency electromagnetic field (EMF), which is used in mobile phones. A low frequency EMF is reported to suppress melatonin synthesis. The aim of this study was to clarify the effects on melatonin synthesis in rats after short term exposure to a 1439 MHz time division multiple access (TDMA) EMF. The average specific absorption ratio (SAR) of the brain was 7.5 W/kg, and the average SARs of the whole body were 1.9 and 2.0 W/kg for male and female rats, respectively. A total of 208 male and female rats were investigated. After acclimatization to a 12 h light-dark (LD) cycle, serum and pineal melatonin levels together with pineal serotonin level under a dark condition (less than 1 lux) were examined by radioimmunoassay. No significant differences in melatonin and serotonin levels were observed between the exposure, sham, and cage control groups. These results suggest that short term exposure to a 1439 MHz TDMA EMF, which is about four times stronger than that emitted by mobile phones, does not alter melatonin and serotonin synthesis in rats. Further investigations on the effects of long term exposure are warranted.

Heikkinen P, Kosma VM, Hongisto T, Huuskonen H, Hyysalo P, Komulainen H, Kumlin T, Lahtinen T, Lang S, Puranen L, Juutilainen J. Effects of Mobile Phone Radiation on X-Ray-Induced Tumorigenesis in Mice. *Radiat Res* 156(6):775-785, 2001.

The increased use of mobile phones has raised the question of possible health effects of such devices, particularly the risk of cancer. It seems unlikely that the low-level radiofrequency (RF) radiation emitted by them would damage DNA directly, but its ability to act as a tumor promoter is less well characterized. In the current study, we evaluated the effect of low-level RF radiation on the development of cancer initiated in mice by ionizing radiation. Two hundred female CBA/S mice were randomized into four equal groups at the age of 3 to 5 weeks. The mice in all groups except the cage-control group were exposed to ionizing radiation at the beginning of the study and then to RF radiation for 1.5 h per day, 5 days a week for 78 weeks. One group was exposed to continuous NMT (Nordic Mobile Telephones)-type frequency-modulated RF radiation at a frequency of 902.5 MHz and a nominal average specific absorption rate (SAR) of 1.5 W/kg. Another group was exposed to pulsed GSM (Global System for Mobile)-type RF radiation (carrier-wave frequency 902.4 MHz, pulse frequency 217 Hz) at a nominal average SAR of 0.35 W/kg. The control animals were sham-exposed. Body weight, clinical signs, and food and water consumption were recorded regularly. Hematological examinations and histopathological analyses of all lesions and major tissues were performed on all animals. The RF-radiation exposures did not increase the incidence of any neoplastic lesion significantly. We conclude that the results do not provide evidence for cancer promotion by RF radiation emitted by mobile phones.

Heikkinen P, Kosma VM, Alhonen L, Huuskonen H, Komulainen H, Kumlin T, Laitinen JT, Lang S, Puranen L, Juutilainen J. Effects of mobile phone radiation on UV-induced skin tumourigenesis in ornithine decarboxylase

transgenic and non-transgenic mice. *Int J Radiat Biol* 79(4):221-233, 2003.

Purpose: The effects of low-level radiofrequency radiation (RFR) on ultraviolet (UV)-induced skin tumorigenesis were evaluated in ornithine decarboxylase (ODC) and non-transgenic mice. **Materials and methods:** Transgenic female mice over-expressing the human ODC gene and their non-transgenic littermates (20 animals in the cage control group, and 45-49 animals in the other groups) were exposed for 52 weeks to UV radiation or a combination of UV radiation and pulsed RFR. The UV dose was 240 Jm⁻² (1.2 x human minimum erythema dose) delivered three times a week. One group of animals was exposed to Digital Advanced Mobile Phone System (DAMPS)-type RFR, the other group to Global System for Mobile (GSM)-type RFR at a nominal average specific absorption rate of 0.5 W kg⁻¹, 1.5 h day⁻¹, for 5 days a week. The skin was carefully palpated weekly for macroscopic tumours. Histopathological analyses of all skin lesions and of a specified dorsal skin area were performed on all animals. **Results:** UV exposure resulted in development of macroscopic skin tumours in 11.5 and 36.8% of non-transgenic and transgenic animals, respectively. The RFR exposures did not give a statistically significant effect on the development of skin tumours in either transgenic or non-transgenic animals, or in combined analysis, but tumour development appeared slightly accelerated especially in non-transgenic animals. No effects of RFR exposures were found on excretion of 6-hydroxymelatonin sulphate into urine or on polyamine levels in dorsal skin. **Conclusion:** RFR exposures did not significantly enhance skin tumourigenesis. However, the slightly accelerated tumour development may warrant further evaluation.

Heikkinen, P., Ernst, H., Huuskonen, H., Komulainen, H., Kumlin, T., Maki-Paakkanen, J., Puranen, L. and Juutilainen, J. No Effects of Radiofrequency Radiation on 3-Chloro-4-(dichloromethyl)-5-hydroxy-2(5H)-furanone-Induced Tumorigenesis in Female Wistar Rats. *Radiat. Res.* 166, 397-408, 2006.

This study evaluated possible effects of radiofrequency (RF) radiation on tumorigenesis induced by the mutagen 3-chloro-4-(dichloromethyl)-5-hydroxy-2(5H)-furanone (MX) given in drinking water. Female Wistar rats aged 7 weeks at the beginning of the experiments were randomly divided into four groups of 72 animals: a cage-control group and three MX-exposed groups (a daily average dose of 1.7 mg MX/kg body weight for 104 weeks), of which two were exposed to 900 MHz pulsed RF radiation and the third served as a sham-RF-radiation group. The RF-radiation groups were exposed 2 h per day, 5 days per week for 104 weeks at nominal whole-body average SARs of 0.3 W/kg and 0.9 W/kg. Complete histopathology was performed on the rats of the three MX-exposed groups. The tumor types and incidences observed in the MX-exposed animals were similar to those reported earlier in MX-exposed female Wistar rats. RF radiation did not statistically significantly affect mortality or organ-specific incidence of any tumor type. The only statistically significant difference was an increase in the combined frequency of vascular tumors of the mesenteric lymph nodes in the high-RF-radiation group compared to the sham-RF-radiation group. However, additional histopathological analysis of the cage-control animals suggested that this difference was due to unusually low frequency of this type of tumor in the sham-RF-radiation group rather than a high frequency in the high-RF-radiation group. With respect to non-neoplastic findings, statistically significant differences between the RF-radiation groups and the sham-RF-radiation group were observed only for single findings in the lacrimal glands, lungs, liver and skin. Such changes are commonly seen in aged rats and were considered to be unrelated to RF radiation. The results of the present study do not support co-carcinogenic effects of low-level long-term RF-radiation exposure in rats.

[Hepworth SJ](#), [Schoemaker MJ](#), [Muir KR](#), [Swerdlow AJ](#), [van Tongeren MJ](#), [McKinney PA](#). Mobile phone use and risk of glioma in adults: case-control study. *BMJ*. 2006 Jan 20; [Epub ahead of print]

OBJECTIVE: To investigate the risk of glioma in adults in relation to mobile phone use. **DESIGN:** Population based case-control study with collection of personal interview data. **SETTING:** Five areas of the United Kingdom. **PARTICIPANTS:** 966 people aged 18 to 69 years diagnosed with a glioma from 1 December 2000 to 29 February 2004 and 1716 controls randomly selected from general practitioner lists. **MAIN OUTCOME MEASURES:** Odds ratios for risk of glioma in relation to mobile phone use. **RESULTS:** The overall odds ratio for regular phone use was 0.94 (95% confidence interval 0.78 to 1.13). There was no relation for risk of glioma and time since first use, lifetime years of use, and cumulative number of calls and hours of use. A significant excess risk for reported phone use ipsilateral to the tumour (1.24, 1.02 to 1.52) was paralleled by a significant reduction in risk (0.75, 0.61 to 0.93) for contralateral use. **CONCLUSIONS:** Use of a mobile phone, either in the short or medium term, is not associated with an increased risk of glioma. This is consistent

with most but not all published studies. The complementary positive and negative risks associated with ipsilateral and contralateral use of the phone in relation to the side of the tumour might be due to recall bias.

Hietanen M, Kovala T, Hamalainen AM, Human brain activity during exposure to radiofrequency fields emitted by cellular phones. *Scand J Work Environ Health* 26(2):87-92, 2000.

OBJECTIVES: The aim of this study was to explore the possible influence of radiofrequency (RF) radiation exposure on human brain function. **METHODS:** The electroencephalographic (EEG) activity of 19 volunteers was quantitatively analyzed. Ten of the subjects were men (28-48 years of age) and 9 were women (32-57 years of age). The sources of exposure were 5 different cellular phones (analogue and digital models) operating at a frequency of 900 MHz or 1800 MHz. The EEG activity was recorded in an awake, closed-eyes situation. Six 30-minute experiments, including 1 sham exposure, were made for each subject. The duration of a real exposure phase was 20 minutes. **RESULTS:** Exposure to one of the phones caused a statistically significant change in the absolute power at the delta band of the EEG recording. However, no difference was seen in the relative power of the same band, and no changes occurred during exposure to other phones at any frequency bands. **CONCLUSIONS:** The findings of this study suggest that exposure to radiofrequency fields emitted by cellular phones has no abnormal effects on human EEG activity. The observed difference in 1 parameter was probably caused by statistical chance.

Hietanen M, Hämäläinen A-M, Husman T. Hypersensitivity symptoms associated with exposure to cellular telephones: No causal link. *Bioelectromagnetics* 23:264-270, 2002.

The hypothesis that there exist hypersensitive persons who perceive subjective symptoms from radiofrequency (RF) fields emitted by hand held mobile phones (cellular phones) was tested using double blind provocation experiments. We also tested whether sensitive subjects are able to determine whether the phone is on or off by sensing RF fields. The study group consisted of 20 volunteers (13 women and 7 men) who reported themselves as being sensitive to cellular phones. The RF exposure sources were one analogue NMT phone (900 MHz) and two digital GSM phones (900 and 1800 MHz). The duration of a test session was 30 min, and three or four sessions were performed in random order for each subject during 1 day. The subjects were asked to report symptoms or sensations as soon as they perceived any abnormal feelings. In addition, the subjects' blood pressure, heart rate, and breathing frequency were monitored every 5 min. The results of the study indicated that various symptoms were reported, and most of them appeared in the head region. However, the number of reported symptoms was higher during sham exposure than during real exposure conditions. In addition, none of the test persons could distinguish real RF exposure from sham exposure. Hence, we conclude that adverse subjective symptoms or sensations, though unquestionably perceived by the test subjects, were not produced by cellular phones.

Higashikubo R, Culbreth VO, Spitz DR, LaRegina MC, Pickard WF, Straube WL, Moros EG, Roti JL, Radiofrequency electromagnetic fields have no effect on the in vivo proliferation of the 9L brain tumor. *Radiat Res* 152(6):665-671, 1999.

The intracranial 9L tumor model was used to determine if exposure to a radiofrequency (RF) electromagnetic field similar to those used in cellular telephone has any effects on the growth of a central nervous system tumor. Fischer 344 rats implanted with different numbers of 9L gliosarcoma cells were exposed to 835.62 MHz frequency-modulated continuous wave (FMCW) or 847.74 MHz code division multiple access (CDMA) RF field with nominal slot-average specific absorption rates in the brain of 0.75 +/- 0.25 W/kg. The animals were exposed to the RF field for 4 h a day, 5 days a week starting 4 weeks prior to and up to 150 days after the implantation of tumor cells. Among sham-exposed animals injected with 2 to 10 viable cells (group 1), the median survival was 70 days, with 27% of the animals surviving at 150 days. The median survival length and final survival fraction for animals injected with 11 to 36 viable cells (group 2) were 52 days and 14%, respectively, while the values for those injected with 37 to 100 cells (group 3) were 45 days and 0%. The animals exposed to CDMA or FMCW had similar survival parameters, and the statistical comparison of the survival curves for each of the groups 1, 2 and 3 showed no significant differences compared to sham-exposed controls.

Higashikubo R, Ragouzis M, Moros EG, Straube WL, Roti Roti JL. Radiofrequency Electromagnetic Fields do not Alter the Cell Cycle Progression of C3H 10T and U87MG Cells. *Radiat Res* 156(6):786-795, 2001.

The effects of exposure to radiofrequency electromagnetic fields (RF EMFs) on cell cycle progression of mouse fibroblasts C3H 10T(1/2) and human glioma U87MG cells were determined by the flow cytometric bromodeoxyuridine pulse-chase method. Cells were exposed to a frequency-modulated continuous wave at 835.62 MHz or a code division multiple access RF EMF centered on 847.74 MHz at an average specific absorption rate of 0.6 W/kg. Five cell cycle parameters, including the transit of cells through G(1), G(2) and S phase and the probability of cell division, were examined immediately after the cells were placed in the fields or after they had been kept in the fields for up to 100 h. The only significant change observed in the study was that associated with C3H 10T(1/2) cell cultures moving into plateau phase toward the later times in the long-exposure experiment. No changes in the cell cycle parameters were observed in cells exposed to either mode of RF EMFs when compared to sham-exposed cells in either of the cell lines studied during the entire experimental period. The results show that exposure to RF EMFs, at the frequencies and power tested, does not have any effect on cell progression in vitro.

Hinrichs H, Heinze HJ. Effects of GSM electromagnetic field on the MEG during an encoding-retrieval task. *Neuroreport*. 15(7):1191-1194, 2004.

Potential effects of GSM 1800 electromagnetic fields (EMF) on verbal memory encoding were investigated by recording event-related magnetic fields (ERMF) from the brain during subsequent memory retrieval. Twelve normal subjects participated in the study. After encoding words from a study list presented in the first phase they had to discriminate old from new words mixed together in a test list presented during the second phase. All subjects performed two experimental sessions, one with exposure to EMF during the study phase, and one without. Exposure to EMF changed an early (350-400 ms) task-specific component of the ERMF indicating an interference of EMF and item encoding. Behavioural measures were not significantly affected. Adverse health effects cannot be derived from these data.

Hirose H, Sakuma N, Kaji N, Suhara T, Sekijima M, Nojima T, Miyakoshi J. Phosphorylation and gene expression of p53 are not affected in human cells exposed to 2.1425 GHz band CW or W-CDMA modulated radiation allocated to mobile radio base stations. *Bioelectromagnetics*. 2006 May 19; [Epub ahead of print]

A large-scale in vitro study focusing on low-level radiofrequency (RF) fields from mobile radio base stations employing the International Mobile Telecommunication 2000 (IMT-2000) cellular system was conducted to test the hypothesis that modulated RF fields induce apoptosis or other cellular stress response that activate p53 or the p53-signaling pathway. First, we evaluated the response of human cells to microwave exposure at a specific absorption rate (SAR) of 80 mW/kg, which corresponds to the limit of the average whole-body SAR for general public exposure defined as a basic restriction by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) guidelines. Second, we investigated whether continuous wave (CW) and wideband code division multiple access (W-CDMA) modulated signal RF fields at 2.1425 GHz induced apoptosis or any signs of stress. Human glioblastoma A172 cells were exposed to W-CDMA radiation at SARs of 80, 250, and 800 mW/kg, and CW radiation at 80 mW/kg for 24 or 48 h. Human IMR-90 fibroblasts from fetal lungs were exposed to both W-CDMA and CW radiation at a SAR of 80 mW/kg for 28 h. Under the RF field exposure conditions described above, no significant differences in the percentage of apoptotic cells were observed between the test groups exposed to RF signals and the sham-exposed negative controls, as evaluated by the Annexin V affinity assay. No significant differences in expression levels of phosphorylated p53 at serine 15 or total p53 were observed between the test groups and the negative controls by the bead-based multiplex assay. Moreover, microarray hybridization and real-time RT-PCR analysis showed no noticeable differences in gene expression of the subsequent downstream targets of p53 signaling involved in apoptosis between the test groups and the negative controls. Our results confirm that exposure to low-level RF signals up to 800 mW/kg does not induce p53-dependent apoptosis, DNA damage, or other stress response in human cells.

Hirose H, Sakuma N, Kaji N, Nakayama K, Inoue K, Sekijima M, Nojima T, Miyakoshi J. Mobile phone base station-emitted radiation does not induce phosphorylation of Hsp27. *Bioelectromagnetics*. 2006 Sep 26; [Epub ahead of print]

An in vitro study focusing on the effects of low-level radiofrequency (RF) fields from mobile radio base stations employing the International Mobile Telecommunication 2000 (IMT-2000) cellular system was conducted to test the

hypothesis that modulated RF fields act to induce phosphorylation and overexpression of heat shock protein hsp27. First, we evaluated the responses of human cells to microwave exposure at a specific absorption rate (SAR) of 80 mW/kg, which corresponds to the limit of the average whole-body SAR for general public exposure defined as a basic restriction in the International Commission on Non-Ionizing Radiation Protection (ICNIRP) guidelines. Second, we investigated whether continuous wave (CW) and Wideband Code Division Multiple Access (W-CDMA) modulated signal RF fields at 2.1425 GHz induced activation or gene expression of hsp27 and other heat shock proteins (hsps). Human glioblastoma A172 cells were exposed to W-CDMA radiation at SARs of 80 and 800 mW/kg for 2-48 h, and CW radiation at 80 mW/kg for 24 h. Human IMR-90 fibroblasts from fetal lungs were exposed to W-CDMA at 80 and 800 mW/kg for 2 or 28 h, and CW at 80 mW/kg for 28 h. Under the RF field exposure conditions described above, no significant differences in the expression levels of phosphorylated hsp27 at serine 82 (hsp27[pS82]) were observed between the test groups exposed to W-CDMA or CW signal and the sham-exposed negative controls, as evaluated immediately after the exposure periods by bead-based multiplex assays. Moreover, no noticeable differences in the gene expression of hsps were observed between the test groups and the negative controls by DNA Chip analysis. Our results confirm that exposure to low-level RF field up to 800 mW/kg does not induce phosphorylation of hsp27 or expression of hsp gene family.

Hirose H, Suhara T, Kaji N, Sakuma N, Sekijima M, Nojima T, Miyakoshi J.

Mobile phone base station radiation does not affect neoplastic transformation in BALB/3T3 cells. *Bioelectromagnetics*. 29(1):55-64, 2008.

A large-scale in vitro study focusing on low-level radiofrequency (RF) fields from mobile radio base stations employing the International Mobile Telecommunication 2000 (IMT-2000) cellular system was conducted to test the hypothesis that modulated RF fields affect malignant transformation or other cellular stress responses. Our group previously reported that DNA strand breaks were not induced in human cells exposed to 2.1425 GHz Wideband Code Division Multiple Access (W-CDMA) radiation up to 800 mW/kg from mobile radio base stations employing the IMT-2000 cellular system. In the current study, BALB/3T3 cells were continuously exposed to 2.1425 GHz W-CDMA RF fields at specific absorption rates (SARs) of 80 and 800 mW/kg for 6 weeks and malignant cell transformation was assessed. In addition, 3-methylcholanthrene (MCA)-treated cells were exposed to RF fields in a similar fashion, to assess for effects on tumor promotion. Finally, the effect of RF fields on tumor co-promotion was assessed in BALB/3T3 cells initiated with MCA and co-exposed to 12-O-tetradecanoylphorbol-13-acetate (TPA). At the end of the incubation period, transformation dishes were fixed, stained with Giemsa, and scored for morphologically transformed foci. No significant differences in transformation frequency were observed between the test groups exposed to RF signals and the sham-exposed negative controls in the non-, MCA-, or MCA plus TPA-treated cells. Our studies found no evidence to support the hypothesis that RF fields may affect malignant transformation. Our results suggest that exposure to low-level RF radiation of up to 800 mW/kg does not induce cell transformation, which causes tumor formation.

Hladky, A, Musil, J, Roth, Z, Urban, P, Blazkova, V, Acute effects of using a mobile phone on CNS functions. *Cent Eur J Public Health* 7(4):165-167. 1999.

Twenty volunteers participated in two experiments exploring the acute effects of using the mobile phone Motorola GSM 8700 on the functions of the CNS. When speaking (5 minutes reading a text from daily newspapers) the electromagnetic fields from the mobile apparatus did not affect the visual evoked potentials. Also a 6-min exposure did not reveal any effect of electromagnetic fields on the results in two tests (memory and attention) performed while speaking into the mobile. On the other hand the phone call itself strongly influenced the performance in a secondary task applying a test of switching attention which is a good model for driving a car. The response and decision speed were significantly worse. This is a proof that even a slight psychological stress involved in calling while driving can be a great risk.

Hocking, B, Preliminary report: symptoms associated with mobile phone use. *Occup Med (Lond)*;48(6):357-360, 1998.

Mobile phone use is ubiquitous, although the alleged health effects of low level radio-frequency radiation (RFR) used in transmission are contentious. Following isolated reports of headache-like symptoms arising in some users, a survey has been conducted to characterize the symptoms sometimes associated with mobile phone usage. A notice of interest in cases was placed in a major medical journal and this was publicized by the media. Respondents were interviewed by telephone

using a structured questionnaire. Forty respondents from diverse occupations described unpleasant sensations such as a burning feeling or a dull ache mainly occurring in the temporal, occipital or auricular areas. The symptoms often began minutes after beginning a call, but could come on later during the day. The symptoms usually ceased within an hour after the call, but could last until evening. Symptoms did not occur when using an ordinary handset, and were different from ordinary headaches. There were several reports suggestive of intra-cranial effects. Three respondents reported local symptoms associated with wearing their mobile phone on their belts. There was one cluster of cases in a workplace. Seventy-five per cent of cases were associated with digital mobile phones. Most of the respondents obtained relief by altering their patterns of telephone usage or type of phone. Cranial and other diverse symptoms may arise associated with mobile phone usage. Physicians and users alike should be alert to this. Further work is needed to determine the range of effects, their mechanism and the possible implications for safety limits of RFR.

Hook GJ, Zhang P, Lagroye I, Li L, Higashikubo R, Moros EG, Straube WL, Pickard WF, Baty JD, Roti Roti JL. Measurement of DNA damage and apoptosis in molt-4 cells after in vitro exposure to radiofrequency radiation. *Radiat Res.* 161(2): 193-200, 2004a.

To determine whether exposure to radiofrequency (RF) radiation can induce DNA damage or apoptosis, Molt-4 T lymphoblastoid cells were exposed with RF fields at frequencies and modulations of the type used by wireless communication devices. Four types of frequency/modulation forms were studied: 847.74 MHz code-division multiple-access (CDMA), 835.62 MHz frequency-division multiple-access (FDMA), 813.56 MHz iDEN(R) (iDEN), and 836.55 MHz time-division multiple-access (TDMA). Exponentially growing cells were exposed to RF radiation for periods up to 24 h using a radial transmission line (RTL) exposure system. The specific absorption rates used were 3.2 W/kg for CDMA and FDMA, 2.4 or 24 mW/kg for iDEN, and 2.6 or 26 mW/kg for TDMA. The temperature in the RTLs was maintained at 37 degrees C +/- 0.3 degrees C. DNA damage was measured using the single-cell gel electrophoresis assay. The annexin V affinity assay was used to detect apoptosis. No statistically significant difference in the level of DNA damage or apoptosis was observed between sham-treated cells and cells exposed to RF radiation for any frequency, modulation or exposure time. Our results show that exposure of Molt-4 cells to CDMA, FDMA, iDEN or TDMA modulated RF radiation does not induce alterations in level of DNA damage or induce apoptosis.

Hook, G. J., Spitz, D. R., Sim, J. E., Higashikubo, R., Baty, J. D., Moros, E. G. and Roti Roti, J. L. Evaluation of Parameters of Oxidative Stress after In Vitro Exposure to FMCW- and CDMA-Modulated Radiofrequency Radiation Fields. *Radiat. Res.* 162, 497–504, 2004b.

The goal of this study was to determine whether radiofrequency (RF) radiation is capable of inducing oxidative stress or affecting the response to oxidative stress in cultured mammalian cells. The two types of RF radiation investigated were frequency-modulated continuous-wave with a carrier frequency of 835.62 MHz (FMCW) and code division multiple access centered on 847.74 MHz (CDMA). To evaluate the effect of RF radiation on oxidative stress, J774.16 mouse macrophage cells were stimulated with γ -interferon (IFN) and bacterial lipopolysaccharide (LPS) prior to exposure. Cell cultures were exposed for 20–22 h to a specific absorption rate of 0.8 W/kg at a temperature of $37.0 \pm 0.3^\circ\text{C}$. Oxidative stress was evaluated by measuring oxidant levels, antioxidant levels, oxidative damage and nitric oxide production. Oxidation of thiols was measured by monitoring the accumulation of glutathione disulfide (GSSG). Cellular antioxidant defenses were evaluated by measuring superoxide dismutase activity (CuZnSOD and MnSOD) as well as catalase and glutathione peroxidase activity. The trypan blue dye exclusion assay was used to measure any changes in viability. The results of these studies indicated that FMCW- and CDMA-modulated RF radiation did not alter parameters indicative of oxidative stress in J774.16 cells. FMCW- and CDMA-modulated fields did not alter the level of intracellular oxidants, accumulation of GSSG or induction of antioxidant defenses in IFN/LPS-stimulated cells. Consistent with the lack of an effect on oxidative stress parameters, no change in toxicity was observed in J774.16 cells after either optimal (with or without inhibitors of nitric oxide synthase) or suboptimal stimulation.

Hours M, Bernard M, Montestrucq L, Arslan M, Bergeret A, Deltour I, Cardis E. [Cell Phones and Risk of brain and acoustic nerve tumours: the French INTERPHONE case-control study.] Rev Epidemiol Sante Publique. 2007 Sep 10; [Epub ahead of print]

[Article in French]

BACKGROUND: Use of cell phones has increased dramatically since 1992 when they were first introduced in France. Certain electromagnetic fields (at extremely low frequency) have been recognized as possibly carcinogenic by the International Agency for Research on Cancer. Given the use of radiofrequency technology in cell phones, the rapid increase in the number of cell phones has generated concerns about the existence of a potential health hazard. To evaluate the relationship between the use of cell phones and the development of tumors of the head, a multicentric international study (INTERPHONE), coordinated by the International Agency for Research on Cancer, was carried out in 13 countries. This publication reports the results of the French part of the INTERPHONE study. **METHODS:** INTERPHONE is a case-control study focused on tumors of the brain and central nervous system: gliomas, meningiomas and neuromas of cranial nerves. Eligible cases were men and women, residents of Paris or Lyon, aged 30-59, newly diagnosed with a first primary tumor between February 2001 and August 2003. The diagnoses were all either histologically confirmed or based upon unequivocal radiological images. Controls were matched for gender, age (± 5 years) and place of residence. They were randomly drawn from electoral rolls. Detailed information was collected for all subjects during a computer-assisted face-to-face interview. Conditional logistic regression was used to estimate the odds ratio (OR) for an association between the use of cell phones and risk of each type of cancer. **RESULTS:** Regular cell phone use was not associated with an increased risk of neuroma (OR=0,92; 95% confidence interval=[0.53-1.59]), meningioma (OR=0,74; 95% confidence interval=[0.43-1.28]) or glioma (OR=1.15; 95% confidence interval=[0.65-2.05]). Although these results are not statistically significant, a general tendency was observed for an increased risk of glioma among the heaviest users: long-term users, heavy users, users with the largest numbers of telephones. **CONCLUSION:** No significant increased risk for glioma, meningioma or neuroma was observed among cell phone users participating in Interphone. The statistical power of the study is limited, however. Our results, suggesting the possibility of an increased risk among the heaviest users, therefore need to be verified in the international INTERPHONE analyses.

Hoyto A, Sihvonen AP, Alhonen L, Juutilainen J, Naarala J Modest increase in temperature affects ODC activity in L929 cells: low-level radiofrequency radiation does not. Radiat Environ Biophys. 2006 Jul 19; [Epub ahead of print]

The effects of low-level radiofrequency (RF) radiation and elevated temperature on ornithine decarboxylase (ODC) activity were investigated in murine L929 fibroblasts. The cells were exposed at 900 MHz either to a pulse-modulated (pulse frequency 217 Hz; GSM-type modulation) or a continuous wave signal at specific absorption rate (SAR) levels of 0.2 W kg⁻¹ (0.1-0.3 W kg⁻¹) and 0.4 W kg⁻¹ (0.3-0.5 W kg⁻¹) for 2, 8, or 24 h. RF radiation did not affect cellular ODC activity. However, a slight increase in temperature (0.8-0.9 degrees C) in the exposure system lead to decreased ODC activity in cell cultures. This was verified by tests in which cells were exposed to different temperatures in incubators. The results show that ODC activity is sensitive to small temperature differences in cell cultures. Hence, a precise temperature control in cellular ODC activity studies is needed.

Höytö A, Luukkonen J, Juutilainen J, Naarala J. Proliferation, oxidative stress and cell death in cells exposed to 872 MHz radiofrequency radiation and oxidants. Radiat. Res. 170(2):235-243, 2008.

Human SH-SY5Y neuroblastoma and mouse L929 fibroblast cells were exposed to 872 MHz radiofrequency (RF) radiation using continuous waves (CW) or a modulated signal similar to that emitted by GSM mobile phones at a specific absorption rate (SAR) of 5 W/kg in isothermal conditions. To investigate possible combined effects with other agents, menadione was used to induce reactive oxygen species, and tert-butylhydroperoxide (t-BOOH) was used to induce lipid peroxidation. After 1 or 24 h of exposure, reduced cellular glutathione levels, lipid peroxidation, proliferation, caspase 3 activity, DNA fragmentation and viability were measured. Two statistically significant differences related to RF radiation were observed: Lipid peroxidation induced by t-BOOH was increased in SH-SY5Y (but not in L929) cells, and menadione-induced caspase 3 activity was increased in L929 (but not in SH-SY5Y) cells. Both differences were statistically significant only for the GSM-modulated signal. The other end points were not significantly affected in any of the experimental conditions, and no effects were observed from exposure to RF radiation alone. The positive findings may be due to chance, but they may also reflect effects that occur only in cells sensitized by chemical stress. Further studies are required to investigate the reproducibility and dose response of the possible effects.

Hruby R, Neubauer G, Kuster N, Frauscher M Study on potential effects of "902-MHz GSM-type Wireless Communication Signals" on DMBA-induced mammary tumours in Sprague-Dawley rats. Mutat Res. 649(1-2):34-44, 2008.

The aim of the study was to detect whether long-term exposure to "902-MHz GSM-type Wireless Communication Signals" ("radio-frequency (RF)-exposure") would affect 7,12-dimethylbenz(a)anthracene (DMBA)-induced mammary tumours in female Sprague-Dawley rats. Five hundred female rats were each given a single oral dose of 17mg DMBA per kg body weight (bw) at an age of 46-48 days. Three groups of 100 animals each were RF-exposed (902MHz; crest factor 8; pulse width=0.57ms) from the next day onwards to normal whole-body averaged doses (expressed as specific absorption rate, SAR) of 0.4, 1.3 or 4.0W/kg bw (low/mid/high-dose group) for 4h/d, 5d/week, during 6 months. A sham-exposed and a cage-control group remained without RF-exposure ($<0.01\text{mW/kg}$). Animals were weekly weighed and palpated for mammary tumours; all mammary glands were examined histopathologically. There were several statistically significant differences between RF-exposed groups and the sham-exposed group, as follows: All RF-exposed groups had, at different times, significantly more palpable tissue masses. There were fewer animals with benign neoplasms, but more with malignant tumours in the high-dose group. In addition, there were more adenocarcinomas in the low-dose group, more malignant neoplasms in the low- and high-dose groups, more animals with adenocarcinomas in the high-dose group, and fewer animals with fibroadenomas in the low- and mid-dose groups. The cage-control group had, when compared with the sham-exposed group, statistically significantly more palpable tissue masses, more benign and also more malignant neoplasms. The cage-control group had in most aspects the highest incidence and malignancy of neoplasms among all groups. None of the above findings in RF-exposed animals produced a clear dose-response relation and the responses of the cage-control group were either similar to or stronger than those of any of the RF-exposed group. The significant differences between the sham-exposed animals and one or more RF-exposed groups may be interpreted as evidence of an effect of RF-exposure. In the context of the results of the cage-control group, in the light of controversial results reported in the literature, and given the fact that the DMBA-mammary tumour model is known to be prone to high variations in the results, it is the authors' opinion that the differences between the groups are rather incidental ones.

Huang TQ, Lee JS, Kim TH, Pack JK, Jang JJ, Seo JS. Effect of radiofrequency radiation exposure on mouse skin tumorigenesis initiated by 7,12-dimethylbenz[alpha]anthracene. Int J Radiat Biol. 81(12):861-867, 2005.

Purpose: Although radiofrequency (RF) radiation is not considered mutagenic, it has been suggested as a promoter of tumorigenesis. To study if RF radiation has a tumor promoting effect, we exposed mice with skin tumorigenesis initiated by 7,12-dimethylbenz[a]anthracene (DMBA) to RF radiation. Materials and methods: Eighty male ICR mice were subjected to a single DMBA application (100 microg/100 microl acetone/mouse) on shaved dorsal skin at the age of 7 weeks. After one week, the mice were randomized into four equal groups of 20 mice each: i.e., sham-, 849 MHz-, 1,763 MHz-exposed, and 12-O-tetradecanoylphorbol-13-acetate (TPA)-treated groups. The RF exposure was conducted at a whole body average specific absorption rate (SAR) of 0.4 W/Kg, for 2 cycles of 45 min exposure with a 15 min interval each day, 5 days a week for 19 weeks. The TPA-treated group served as a positive control for skin tumorigenesis and were administered TPA (4 microg/100 microl acetone/mouse) twice weekly without RF exposure. Results: All mice were examined weekly at a macroscopic level. No skin tumors were observed in any groups except in the TPA-treated positive control group. TPA is known tumor promoter in DMBA-induced skin carcinogenesis and tumor incidence in the TPA treated group was 95%. At week 20 after DMBA initiation, skin tissues were analyzed immunohistochemically using anti-proliferating cell nuclear antigen (PCNA) antibody. No differences were observed by pathological examination or by PCNA staining between the sham- and the RF-exposed groups. The expression of cyclin D1 and c-fos were detected only in the tumorous skin tissues of the TPA-treated group. Conclusion: No evidence was found that RF radiation serves as a tumor promoter for skin tumors. Our data suggests that 849 MHz and 1,763 MHz RF radiations, similar to those emitted from mobile phones, do not have any promoting effect on skin tumor development in DMBA-initiated mice.

Huang TQ, Lee MS, Oh E, Zhang BT, Seo JS, Park WY. Molecular responses of Jurkat T-cells to 1763 MHz radiofrequency radiation. Int J Radiat Biol. 84(9):734-741, 2008.

PURPOSE: The biological effects of exposure to mobile phone emitted radiofrequency (RF) radiation are the subject of intense study, yet the hypothesis that RF exposure is a potential health hazard remains controversial. In this paper, we monitored cellular and molecular changes in Jurkat human T lymphoma cells after irradiating with 1763 MHz RF

radiation to understand the effect on RF radiation in immune cells. **MATERIALS AND METHODS:** Jurkat T-cells were exposed to RF radiation to assess the effects on cell proliferation, cell cycle progression, DNA damage and gene expression. Jurkat cells were exposed to 1763 MHz RF radiation at 10 W/kg specific absorption rate (SAR) and compared to sham exposed cells. **RESULTS:** RF exposure did not produce significant changes in cell numbers, cell cycle distributions, or levels of DNA damage. In genome-wide analysis of gene expressions, there were no genes changed more than two-fold upon RF-radiation while ten genes change to 1.3 approximately 1.8-fold. Among ten genes, two cytokine receptor genes such as chemokine (C-X-C motif) receptor 3 (CXCR3) and interleukin 1 receptor, type II (IL1R2) were down-regulated upon RF radiation, but they were not directly related to cell proliferation or DNA damage responses. **CONCLUSION:** These results indicate that the alterations in cell proliferation, cell cycle progression, DNA integrity or global gene expression was not detected upon 1763 MHz RF radiation under 10 W/kg SAR for 24 h to Jurkat T cells.

Huang TQ, Lee MS, Oh EH, Kalinec F, Zhang BT, Seo JS, Park WY. Characterization of biological effect of 1763 MHz radiofrequency exposure on auditory hair cells. Int J Radiat Biol. 84(11):909-915, 2008.

Purpose: Radiofrequency (RF) exposure at the frequency of mobile phones has been reported not to induce cellular damage in in vitro and in vivo models. We chose HEI-OC1 immortalized mouse auditory hair cells to characterize the cellular response to 1763 MHz RF exposure, because auditory cells could be exposed to mobile phone frequencies. **Materials and methods:** Cells were exposed to 1763 MHz RF at a 20 W/kg specific absorption rate (SAR) in a code division multiple access (CDMA) exposure chamber for 24 and 48 h to check for changes in cell cycle, DNA damage, stress response, and gene expression. **Results:** Neither of cell cycle changes nor DNA damage was detected in RF-exposed cells. The expression of heat shock proteins (HSP) and the phosphorylation of mitogen-activated protein kinases (MAPK) did not change, either. We tried to identify any alteration in gene expression using microarrays. Using the Applied Biosystems 1700 full genome expression mouse microarray, we found that only 29 genes (0.09% of total genes examined) were changed by more than 1.5-fold on RF exposure. **Conclusion:** From these results, we could not find any evidence of the induction of cellular responses, including cell cycle distribution, DNA damage, stress response and gene expression, after 1763 MHz RF exposure at an SAR of 20 W/kg in HEI-OC1 auditory hair cells.

Huber R, Graf T, Cote KA, Wittmann L, Gallmann E, Matter D, Schuderer J, Kuster N, Borbely AA, Achermann P, Exposure to pulsed high-frequency electromagnetic field during waking affects human sleep EEG. *Neuroreport* 11(15):3321-3325, 2000.

The aim of the study was to investigate whether the electromagnetic field (EMF) emitted by digital radiotelephone handsets affects brain physiology. Healthy, young male subjects were exposed for 30 min to EMF (900 MHz; spatial peak specific absorption rate 1 W/kg) during the waking period preceding sleep. Compared with the control condition with sham exposure, spectral power of the EEG in non-rapid eye movement sleep was increased. The maximum rise occurred in the 9.75-11.25 Hz and 12.5-13.25 Hz band during the initial part of sleep. These changes correspond to those obtained in a previous study where EMF was intermittently applied during sleep. Unilateral exposure induced no hemispheric asymmetry of EEG power. The present results demonstrate that exposure during waking modifies the EEG during subsequent sleep. Thus the changes of brain function induced by pulsed high-frequency EMF outlast the exposure period.

Huber R, Treyer V, Borbély AA, Schuderer J, Gottselig JM, Landolt H-P, Werth E, Berthold T, Kuster N, Buck A, Achermann P, Electromagnetic fields, such as those from mobile phones, alter regional cerebral blood flow and sleep and waking EEG. *J Sleep Res* 11: 289-295, 2002.

Usage of mobile phones is rapidly increasing, but there is limited data on the possible effects of electromagnetic field (EMF) exposure on brain physiology. We investigated the effect of EMF vs. sham control exposure on waking regional cerebral blood flow (rCBF) and on waking and sleep electroencephalogram (EEG) in humans. In Experiment 1, positron emission tomography (PET) scans were taken after unilateral head exposure to 30-min pulse-modulated 900 MHz electromagnetic field (pm-EMF). In Experiment 2, night-time sleep was polysomnographically recorded after EMF exposure. Pulse-modulated EMF exposure increased relative rCBF in the dorsolateral prefrontal cortex ipsilateral to exposure. Also, pm-EMF exposure enhanced EEG power in the alpha frequency range prior to sleep onset and in the spindle frequency range during stage 2 sleep. Exposure to EMF without pulse modulation did not enhance power in the

waking or sleep EEG. We previously observed EMF effects on the sleep EEG (A. A. Borbély, R. Huber, T. Graf, B. Fuchs, E. Gallmann and P. Achermann. *Neurosci. Lett.*, 1999, 275: 207-210; R. Huber, T. Graf, K. A. Cote, L. Wittmann, E. Gallmann, D. Matter, J. Schuderer, N. Kuster, A. A. Borbély, and P. Achermann. *Neuroreport*, 2000, 11: 3321-3325), but the basis for these effects was unknown. The present results show for the first time that (1) pm-EMF alters waking rCBF and (2) pulse modulation of EMF is necessary to induce waking and sleep EEG changes. Pulse-modulated EMF exposure may provide a new, non-invasive method for modifying brain function for experimental, diagnostic and therapeutic purposes.

Huber R, Schuderer J, Graf T, Jutz K, Borbely AA, Kuster N, Achermann P. Radio frequency electromagnetic field exposure in humans: Estimation of SAR distribution in the brain, effects on sleep and heart rate. *Bioelectromagnetics* 24(4):262-276, 2003.

In two previous studies we demonstrated that radiofrequency electromagnetic fields (RF EMF) similar to those emitted by digital radiotelephone handsets affect brain physiology of healthy young subjects exposed to RF EMF (900 MHz; spatial peak specific absorption rate [SAR] 1 W/kg) either during sleep or during the waking period preceding sleep. In the first experiment, subjects were exposed intermittently during an 8 h nighttime sleep episode and in the second experiment, unilaterally for 30 min prior to a 3 h daytime sleep episode. Here we report an extended analysis of the two studies as well as the detailed dosimetry of the brain areas, including the assessment of the exposure variability and uncertainties. The latter enabled a more in depth analysis and discussion of the findings. Compared to the control condition with sham exposure, spectral power of the non-rapid eye movement sleep electroencephalogram (EEG) was initially increased in the 9-14 Hz range in both experiments. No topographical differences with respect to the effect of RF EMF exposure were observed in the two experiments. Even unilateral exposure during waking induced a similar effect in both hemispheres. Exposure during sleep reduced waking after sleep onset and affected heart rate variability. Exposure prior to sleep reduced heart rate during waking and stage 1 sleep. The lack of asymmetries in the effects on sleep EEG, independent of bi- or unilateral exposure of the cortex, may indicate involvement of subcortical bilateral projections to the cortex in the generation of brain function changes, especially since the exposure of the thalamus was similar in both experiments (approx. 0.1 W/kg).

Huber R, Treyer V, Schuderer J, Berthold T, Buck A, Kuster N, Landolt HP, Achermann P. Exposure to pulse-modulated radio frequency electromagnetic fields affects regional cerebral blood flow. *Eur J Neurosci.* 21(4):1000-1006, 2005.

We investigated the effects of radio frequency electromagnetic fields (RF EMF) similar to those emitted by mobile phones on waking regional cerebral blood flow (rCBF) in 12 healthy young men. Two types of RF EMF exposure were applied: a 'base-station-like' and a 'handset-like' signal. Positron emission tomography scans were taken after 30 min unilateral head exposure to pulse-modulated 900 MHz RF EMF (10 g tissue-averaged spatial peak-specific absorption rate of 1 W/kg for both conditions) and sham control. We observed an increase in relative rCBF in the dorsolateral prefrontal cortex on the side of exposure. The effect depended on the spectral power in the amplitude modulation of the RF carrier such that only 'handset-like' RF EMF exposure with its stronger low-frequency components but not the 'base-station-like' RF EMF exposure affected rCBF. This finding supports our previous observation that pulse modulation of RF EMF is necessary to induce changes in the waking and sleep EEG, and substantiates the notion that pulse modulation is crucial for RF EMF-induced alterations in brain physiology.

Hung CS, Anderson C, Horne JA, McEvoy P. Mobile phone 'talk-mode' signal delays EEG-determined sleep onset. *Neurosci Lett.* 2007 May 24; [Epub ahead of print]

Mobile phones signals are pulse-modulated microwaves, and EEG studies suggest that the extremely low-frequency (ELF) pulse modulation has sleep effects. However, 'talk', 'listen' and 'standby' modes differ in the ELF (2, 8, and 217Hz) spectral components and specific absorption rates, but no sleep study has differentiated these modes. We used a GSM900 mobile phone controlled by a base-station simulator and a test SIM card to simulate these three specific modes, transmitted at 12.5% (23dBm) of maximum power. At weekly intervals, 10 healthy young adults, sleep restricted to 6h, were randomly and single-blind exposed to one of: talk, listen, standby and sham (nil signal) modes, for 30min, at 13:30h, whilst lying in a sound-proof, lit bedroom, with a thermally insulated silent phone beside the right ear. Bipolar EEGs were recorded continuously, and subjective ratings of sleepiness obtained every 3min (before, during and after exposure). After

exposure the phone and base-station were switched off, the bedroom darkened, and a 90min sleep opportunity followed. We report on sleep onset using: (i) visually scored latency to onset of stage 2 sleep, (ii) EEG power spectral analysis. There was no condition effect for subjective sleepiness. Post-exposure, sleep latency after talk mode was markedly and significantly delayed beyond listen and sham modes. This condition effect over time was also quite evident in 1-4Hz EEG frontal power, which is a frequency range particularly sensitive to sleep onset. It is possible that 2, 8, 217Hz modulation may differentially affect sleep onset.

Huss A, Egger M, Hug K, Huwiler-Müntener K, Rösli M, Gomes D, Da Ros MA Source of funding and results of studies of health effects of mobile phone use: systematic review of experimental studies. *Cien Saude Colet.* 13(3):1005-1012, 2008.

There is concern regarding the possible health effects of cellular telephone use. We conducted a systematic review of studies of controlled exposure to radiofrequency radiation with health-related outcomes (electroencephalogram, cognitive or cardiovascular function, hormone levels, symptoms, and subjective well-being). We searched Embase, Medline, and a specialist database in February 2005 and scrutinized reference lists from relevant publications. Data on the source of funding, study design, methodologic quality, and other study characteristics were extracted. The primary outcome was the reporting of at least one statistically significant association between the exposure and a health-related outcome. Data were analyzed using logistic regression models. Of 59 studies, 12 (20%) were funded exclusively by the telecommunications industry, 11 (19%) were funded by public agencies or charities, 14 (24%) had mixed funding (including industry), and in 22 (37%) the source of funding was not reported. Studies funded exclusively by industry reported the largest number of outcomes, but were least likely to report a statistically significant result. The interpretation of results from studies of health effects of radiofrequency radiation should take sponsorship into account.

Ilhan A, Gurel A, Armutcu F, Kamisli S, Iraz M, Akyol O, Ozen S. Ginkgo biloba prevents mobile phone-induced oxidative stress in rat brain. *Clin Chim Acta.* 340(1-2): 153-162, 2004.

BACKGROUND: The widespread use of mobile phones (MP) in recent years has raised the research activities in many countries to determine the consequences of exposure to the low-intensity electromagnetic radiation (EMR) of mobile phones. Since several experimental studies suggest a role of reactive oxygen species (ROS) in EMR-induced oxidative damage in tissues, in this study, we investigated the effect of Ginkgo biloba (Gb) on MP-induced oxidative damage in brain tissue of rats. **METHODS:** Rats (EMR+) were exposed to 900 MHz EMR from MP for 7 days (1 h/day). In the EMR+Gb groups, rats were exposed to EMR and pretreated with Gb. Control and Gb-administrated groups were produced by turning off the mobile phone while the animals were in the same exposure conditions. Subsequently, oxidative stress markers and pathological changes in brain tissue were examined for each groups. **RESULTS:** Oxidative damage was evident by the: (i) increase in malondialdehyde (MDA) and nitric oxide (NO) levels in brain tissue, (ii) decrease in brain superoxide dismutase (SOD) and glutathione peroxidase (GSH-Px) activities and (iii) increase in brain xanthine oxidase (XO) and adenosine deaminase (ADA) activities. These alterations were prevented by Gb treatment. Furthermore, Gb prevented the MP-induced cellular injury in brain tissue histopathologically. **CONCLUSION:** Reactive oxygen species may play a role in the mechanism that has been proposed to explain the biological side effects of MP, and Gb prevents the MP-induced oxidative stress to preserve antioxidant enzymes activity in brain tissue.

Imaida, K, Taki, M, Watanabe, S, Kamimura, Y, Ito, T, Yamaguchi, T, Ito, N, Shirai, T, The 1.5 GHz electromagnetic near-field used for cellular phones does not promote rat liver carcinogenesis in a medium-term liver bioassay. *Jpn J Cancer Res* 89(10):995-1002, 1998.

We have recently established that local exposure to a 929.2 MHz electromagnetic near-field, used for cellular phones, does not promote rat liver carcinogenesis in a medium-term bioassay system. In the present study, a 1.439 GHz electromagnetic near-field (EMF), another microwave band employed for cellular phones in Japan, was similarly investigated. Time division multiple access (TDMA) signals for the Personal Digital Cellular (PDC) Japanese cellular telephone standard system were directed to rats through a quarter-wavelength monopole antenna. Numerical dosimetry showed that the peak SARs within the liver were 1.91-0.937 W/kg, while the whole-body average specific absorption rates (SARs) were 0.680-0.453 W/kg, when the time-averaged antenna radiation power was 0.33 W. Exposure was for 90

min a day, 5 days a week, over 6 weeks, to male F344 rats given a single dose of diethylnitrosamine (200 mg/kg, i.p.) 2 weeks previously. At week 3, all rats were subjected to a two-thirds partial hepatectomy. At week 8, the experiment was terminated and the animals were killed. Carcinogenic potential was scored by comparing the numbers and areas of the induced glutathione S-transferase placental form (GST-P)-positive foci in the livers of exposed (48) and sham-exposed rats (48). Despite increased serum levels of corticosterone, adrenocorticotrophic hormone (ACTH) and melatonin, the numbers and the areas of GST-P-positive foci were not significantly altered by the exposure. These findings clearly indicated that local body exposure to a 1.439 GHz EMF, as in the case of a 929.2 MHz field, has no promoting effect on rat liver carcinogenesis in the present model.

Imaida K, Taki M, Yamaguchi T, Ito T, Watanabe S, Wake K, Aimoto A, Kamimura Y, Ito N, Shirai T, Lack of promoting effects of the electromagnetic near-field used for cellular phones (929.2 MHz) on rat liver carcinogenesis in a medium-term liver bioassay. *Carcinogenesis* 19(2):311-314, 1998.

The possible cancer promotion potential of local exposure to a pulse modulated 929.2 MHz electromagnetic near-field on chemically-initiated rat liver carcinogenesis was investigated employing a medium-term bioassay. A 929.2-MHz electromagnetic near-field of time division multiple access (TDMA) signal for PDC (Personal Digital Cellular, Japanese cellular telephone standard) system was directed to rats through a quarter-wavelength monopole antenna. Maximum local specific absorption rates (SARs) on temporal average were 7.2-6.6 W/kg within the whole body and 2.0-1.7 W/kg within the liver, which was the target organ. The whole-body average SARs on temporal average were 0.80-0.58 W/kg. Temporal peak SARs had three times these values due to the duty ratio of the PDC signal. Exposure was for 90 min a day, 5 days a week, over 6 weeks. The exposure apparatus was specially designed for this experiment, to allow exposure of the lateral mid-section of the rat body to the electromagnetic near-field. Male F344 rats, 6 week-old, were initially (at week 0) given a single dose of diethylnitrosamine (DEN, 200 mg/kg body wt, i.p.). At 2 weeks later, exposure (48 rats) or sham-exposure (48 rats) was started. The exposure of electromagnetic near-fields was performed using the exposure apparatus mentioned above. At week 3, all rats were subjected to a 2/3 partial hepatectomy. At week 8 (i.e. after 6 weeks exposure or sham-exposure), the experiment was terminated and all rats were killed. Carcinogenic potential was scored by comparing the numbers and areas of the induced glutathione S-transferase placental form (GST-P) positive foci in the livers of the exposed and sham-exposed rats. A further group of 24 animals, given only DEN and partial hepatectomy, served as the controls. The numbers (no./cm²) of GST-P positive foci were 4.61 +/- 1.77, 5.21 +/- 1.92 (P < 0.05, versus control) and 4.09 +/- 1.47 and the areas (mm²/cm²) were 0.30 +/- 0.16, 0.36 +/- 0.21 and 0.28 +/- 0.15, for the exposed, sham-exposed and control groups, respectively. There were no significant differences between the exposed and sham-exposed groups. These findings clearly indicated that local body exposure to a 929.2-MHz field, modulated in a PDC waveform, has no significant effect on rat liver carcinogenesis under the experimental conditions employed.

Inomata-Terada S, Okabe S, Arai N, Hanajima R, Terao Y, Frubayashi T, Ugawa Y. Effects of high frequency electromagnetic field (EMF) emitted by mobile phones on the human motor cortex. *Bioelectromagnetics*. 2007 May 21; [Epub ahead of print]

We investigated whether the pulsed high frequency electromagnetic field (EMF) emitted by a mobile phone has short term effects on the human motor cortex. We measured motor evoked potentials (MEPs) elicited by single pulse transcranial magnetic stimulation (TMS), before and after mobile phone exposure (active and sham) in 10 normal volunteers. Three sites were stimulated (motor cortex (CTX), brainstem (BST) and spinal nerve (Sp)). The short interval intracortical inhibition (SICI) of the motor cortex reflecting GABAergic interneuronal function was also studied by paired pulse TMS method. MEPs to single pulse TMS were also recorded in two patients with multiple sclerosis showing temperature dependent neurological symptoms (hot bath effect). Neither MEPs to single pulse TMS nor the SICI was affected by 30 min of EMF exposure from mobile phones or sham exposure. In two MS patients, mobile phone exposure had no effect on any parameters of MEPs even though conduction block occurred at the corticospinal tracts after taking a bath. As far as available methods are concerned, we did not detect any short-term effects of 30 min mobile phone exposure on the human motor cortical output neurons or interneurons even though we can not exclude the possibility that we failed to detect some mild effects due to a small sample size in the present study. This is the first study of MEPs after electromagnetic exposure from a mobile phone in neurological patients.

Inskip PD, Tarone RE, Hatch EE, Wilcosky TC, Shapiro WR, Selker RG, Fine HA, Black PM, Loeffler JS, Linet MS, Cellular-Telephone Use and Brain Tumors. *N Engl J Med* 344(2):79-86, 2001.

Background: Concern has arisen that the use of hand-held cellular telephones might cause brain tumors. If such a risk does exist, the matter would be of considerable public health importance, given the rapid increase worldwide in the use of these devices. Methods: We examined the use of cellular telephones in a case-control study of intracranial tumors of the nervous system conducted between 1994 and 1998. We enrolled 782 patients through hospitals in Phoenix, Arizona; Boston; and Pittsburgh; 489 had histologically confirmed glioma, 197 had meningioma, and 96 had acoustic neuroma. The 799 controls were patients admitted to the same hospitals as the patients with brain tumors for a variety of nonmalignant conditions. Results: As compared with never, or very rarely, having used a cellular telephone, the relative risks associated with a cumulative use of a cellular telephone for more than 100 hours were 0.9 for glioma (95 percent confidence interval, 0.5 to 1.6), 0.7 for meningioma (95 percent confidence interval, 0.3 to 1.7), 1.4 for acoustic neuroma (95 percent confidence interval, 0.6 to 3.5), and 1.0 for all types of tumors combined (95 percent confidence interval, 0.6 to 1.5). There was no evidence that the risks were higher among persons who used cellular telephones for 60 or more minutes per day or regularly for five or more years. Tumors did not occur disproportionately often on the side of head on which the telephone was typically used. Conclusions: These data do not support the hypothesis that the recent use of hand-held cellular telephones causes brain tumors, but they are not sufficient to evaluate the risks among long-term, heavy users and for potentially long induction periods.

Irlenbusch L, Bartsch B, Cooper J, Herget I, Marx B, Raczek J, Thoss F. Influence of a 902.4 MHz GSM signal on the human visual system: Investigation of the discrimination threshold. Bioelectromagnetics. 2007 Jul 24; [Epub ahead of print]

The proximity of a mobile phone to the human eye raises the question as to whether radiofrequency (RF) electromagnetic fields (EMF) affect the visual system. A basic characteristic of the human eye is its light sensitivity, making the visual discrimination threshold (VDThr) a suitable parameter for the investigation of potential effects of RF exposure on the eye. The VDThr was measured for 33 subjects under standardized conditions. Each subject took part in two experiments (RF-exposure and sham-exposure experiment) on different days. In each experiment, the VDThr was measured continuously in time intervals of about 10 s for two periods of 30 min, having a break of 5 min in between. The sequence of the two experiments was randomized, and the study was single blinded. During the RF exposure, a GSM signal of 902.4 MHz (pulsed with 217 Hz) was applied to the subjects. The power flux density of the electromagnetic field at the subject location (in the absence of the subject) was 1 W/m², and numerical dosimetry calculations determined corresponding maximum local averaged specific absorption rate (SAR) values in the retina of SAR(1 g) = 0.007 W/kg and SAR(10 g) = 0.003 W/kg. No statistically significant differences in the VDThr were found in comparing the data obtained for RF exposure with those for sham exposure.

Irmak MK, Fadillioglu E, Gulec M, Erdogan H, Yagmurca M, Akyol O. Effects of electromagnetic radiation from a cellular telephone on the oxidant and antioxidant levels in rabbits. Cell Biochem Funct. 20(4):279-283, 2002.

The number of reports on the effects induced by electromagnetic radiation (EMR) in various cellular systems is still increasing. Until now no satisfactory mechanism has been proposed to explain the biological effects of this radiation. Oxygen free radicals may play a role in mechanisms of adverse effects of EMR. This study was undertaken to investigate the influence of electromagnetic radiation of a digital GSM mobile telephone (900 MHz) on oxidant and antioxidant levels in rabbits. Adenosine deaminase, xanthine oxidase, catalase, myeloperoxidase, superoxide dismutase (SOD) and glutathione peroxidase activities as well as nitric oxide (NO) and malondialdehyde levels were measured in sera and brains of EMR-exposed and sham-exposed rabbits. Serum SOD activity increased, and serum NO levels decreased in EMR-exposed animals compared to the sham group. Other parameters were not changed in either group. This finding may indicate the possible role of increased oxidative stress in the pathophysiology of adverse effect of EMR. Decreased NO levels may also suggest a probable role of NO in the adverse effect.

Irmak MK, Oztas E, Yagmurca M, Fadillioglu E, Bakir B. Effects of electromagnetic radiation from a cellular telephone on epidermal Merkel cells. J Cutan Pathol. 30(2):135-138, 2003.

The number of reports on the effects induced by electromagnetic radiation (EMR) from cellular telephones in various cellular systems is still increasing. Until now, no satisfactory mechanism has been proposed to explain the biological effects of this radiation except a role suggested for mast cells. Merkel cells may also play a role in the mechanisms of biological effects of EMR. This study was undertaken to investigate the influence of EMR from a cellular telephone (900 MHz) on Merkel cells in rats. A group of rats was exposed to a cellular telephone in speech position for 30 min. Another group of rats was sham-exposed under the same environmental conditions for 30 min. Exposure led to significantly higher exocytotic activity in Merkel cells compared with the sham exposure group. This finding may indicate the possible role of Merkel cells in the pathophysiology of the effects of EMR.

Ivaschuk OI, Jones RA, Ishida-Jones T, Haggren W, Adey WR, Phillips JL, Exposure of nerve growth factor-treated PC12 rat pheochromocytoma cells to a modulated radiofrequency field at 836.55 MHz: effects on c-jun and c-fos expression. *Bioelectromagnetics* 18(3):223-229, 1997.

Rat PC12 pheochromocytoma cells have been treated with nerve growth factor And then exposed to athermal levels of a packet-modulated radiofrequency field At 836.55 MHz. This signal was produced by a prototype time-domain multiple-access (TDMA) transmitter that conforms to the North American digital cellular telephone standard. Three slot average power densities were used: 0.09, 0.9, and 9 mW/cm². Exposures were for 20, 40, and 60 min and included an intermittent exposure regimen (20 min on/20 min off), resulting in total incubation times of 20, 60, and 100 min, respectively. Concurrent controls were sham exposed. After extracting total cellular RNA, Northern blot analysis was used to assess the expression of the immediate early genes, c-fos and c-jun, in all cell populations. No change in c-fos transcript levels were detected after 20 min exposure at each field intensity (20 min was the only time period at which c-fos message could be detected consistently). Transcript levels for c-jun were altered only after 20 min exposure to 9 mW/cm² (average 38% decrease).

Janssen T, Boege P, von Mikusch-Buchberg J, Raczek J. Investigation of potential effects of cellular phones on human auditory function by means of distortion product otoacoustic emissions. *J Acoust Soc Am.* 117(3 Pt 1):1241-1247, 2005.

Outer hair cells (OHC) are thought to act like piezoelectric transducers that amplify low sounds and hence enable the ear's exquisite sensitivity. Distortion product otoacoustic emissions (DPOAE) reflect OHC function. The present study investigated potential effects of electromagnetic fields (EMF) of GSM (Global System for Mobile Communication) cellular phones on OHCs by means of DPOAEs. DPOAE measurements were performed during exposure, i.e., between consecutive GSM signal pulses, and during sham exposure (no EMF) in 28 normally hearing subjects at tone frequencies around 4 kHz. For a reliable DPOAE measurement, a 900-MHz GSM-like signal was used where transmission pause was increased from 4.034 ms (GSM standard) to 24.204 ms. Peak transmitter power was set to 20 W, corresponding to a specific absorption rate (SAR) of 0.1 W/kg. No significant change in the DPOAE level in response to the EMF exposure was found. However, when undesired side effects on DPOAEs were compensated, in some subjects an extremely small EMF-exposure-correlated change in the DPOAE level (< 1 dB) was observed. In view of the very large dynamic range of hearing in humans (120 dB), it is suggested that this observation is physiologically irrelevant.

Jarupat S, Kawabata A, Tokura H, Borkiewicz A. Effects of the 1900 MHz Electromagnetic Field Emitted from Cellular Phone on Nocturnal Melatonin Secretion. *J Physiol Anthropol Appl Human Sci* 22(1):61-63, 2003.

Exposure to cellular phone EMF caused a significant reduction in salivary melatonin in female human subjects.

Jech R, Sonka K, Ruzicka E, Nebuzelsky A, Bohm J, Juklickova M, Nevsimalova S. Electromagnetic field of mobile phones affects visual event related potential in patients with narcolepsy. *Bioelectromagnetics* 22(7):519-528, 2001.

The effects of the mobile phone (MP) electromagnetic fields on electroencephalography (EEG) and event-related potentials (ERP) were examined. With regard to the reported effects of MP on sleep, 22 patients with narcolepsy-cataplexy were exposed or sham exposed for 45 min to the MP (900 MHz, specific absorption rate 0.06 W/kg) placed close to the right ear in a double blind study. There were no changes of the EEG recorded after the MP exposure. A subgroup of 17 patients was studied on visual ERP recorded during the MP exposure. Using an adapted "odd-ball" paradigm, each patient was instructed to strike a key whenever rare target stimuli were presented. There were three variants of target stimuli (horizontal stripes in (i) left, (ii) right hemifields or (iii) whole field of the screen). The exposure enhanced the positivity of the ERP endogenous complex solely in response to target stimuli in the right hemifield of the screen ($P < 0.01$). The reaction time was shortened by 20 ms in response to all target stimuli ($P < 0.05$). In conclusion, the electromagnetic field of MP may suppress the excessive sleepiness and improve performance while solving a monotonous cognitive task requiring sustained attention and vigilance.

Jensh RP, Behavioral teratologic studies using microwave radiation: is there an increased risk from exposure to cellular phones and microwave ovens? *Reprod Toxicol* 11(4):601-611, 1997.

The objective of the investigations presented in this review was to determine if there are adverse effects due to chronic prenatal microwave exposure in rats at term and/or alterations in neonatal and adult offspring psychophysiological development and growth. Following the establishment of a nonhyperthermal power density level of microwave radiation, pregnant rats were exposed throughout pregnancy to continuous wave 915 MHz, 2450 MHz, or 6000 MHz radiation at power density levels of 10, 20, or 35 mW/cm², respectively. Teratologic evaluation included the following parameters: maternal weight and weight gain; mean litter size; maternal organ weight and organ weight/body weight ratios; body weight ratios of brain, liver, kidneys, and ovaries; maternal peripheral blood parameters including hematocrit, hemoglobin, and white cell counts; number of resorptions and resorption rate; number of abnormalities and abnormality rate; mean term fetal weight. Mothers were rebred, and the second, nonexposed litters were evaluated for teratogenic effects. Exposed offspring were evaluated using the following perinatal and adult tests: eye opening, surface righting, negative geotaxis, auditory startle, air righting, open field, activity wheel, swimming, and forelimb hanging. Offspring were also monitored for weekly weight and weight gain. Animals exposed to 915 MHz did not exhibit any consistent significant alterations in any of the above parameters. Exposure to 2450 MHz resulted only in a significantly increased adult offspring activity level compared to nonexposed offspring. Offspring exposed to 6000 MHz radiation exhibited an initial slight, but significant, retardation in term weight, while mothers had a significantly reduced monocyte count. No changes in any of the other term parameters were observed. A few postnatal parameters were affected in offspring exposed to 6000 MHz. Weekly weights were lower in the exposed offspring, but they recovered by the fifth week. Eye opening was delayed, and there were changes in the water T-maze and open field performance levels. Several organ/body weight ratios differed from those of the control offspring. These results indicate that exposure to 6000 MHz radiation at this power density level may result in subtle long-term neurophysiologic alterations. However, in the absence of a hyperthermic state, the microwave frequencies tested, which included frequencies used in cellular phones and microwave ovens, do not induce a consistent, significant increase in reproductive risk as assessed by classical morphologic and postnatal psychophysiological parameters.

Jia F, Ushiyama A, Masuda H, Lawlor GF, Ohkubo C. Role of blood flow on RF exposure induced skin temperature elevations in rabbit ears. *Bioelectromagnetics*. 2006 Sep 26; [Epub ahead of print]

In this in vivo study, we measured local temperature changes in rabbit pinnae, which were evoked by radiofrequency (RF) exposure for 20 min at localized SAR levels of 0 (sham exposure), 2.3, 10.0, and 34.3 W/kg over 1.0 g rabbit ear tissue. The effects of RF exposures on skin temperature were measured under normal blood flow and without blood flow in the ear. The results showed: (1) physiological blood flow clearly modified RF induced thermal elevation in the pinna as blood flow significantly suppressed temperature increases even at 34.3 W/kg; (2) under normal blood flow conditions, exposures at 2.3 and 10.0 W/kg, approximating existing safety limits for the general public (2 W/kg) and occupational exposure (10 W/kg), did not induce significant temperature rises in the rabbit ear. However, 2.3 W/kg induced local skin temperature elevation under no blood flow conditions. Our results demonstrate that the physiological effects of blood flow should be considered when extrapolating modeling data to living animals, and particular caution is needed when interpreting the results of modeling studies that do not include blood flow.

Johansen C, Boice JD, McLaughlin JK, Olsen JH, Cellular Telephones and Cancer- a Nationwide Cohort Study in Denmark. *J Natl Cancer Inst* 93(3):203-207, 2001.

BACKGROUND: Use of cellular telephones is increasing exponentially and has become part of everyday life. Concerns about possible carcinogenic effects of radiofrequency signals have been raised, although they are based on limited scientific evidence. **METHODS:** A retrospective cohort study of cancer incidence was conducted in Denmark of all users of cellular telephones during the period from 1982 through 1995. Subscriber lists from the two Danish operating companies identified 420 095 cellular telephone users. Cancer incidence was determined by linkage with the Danish Cancer Registry. All statistical tests are two-sided. **RESULTS:** Overall, 3391 cancers were observed with 3825 expected, yielding a significantly decreased standardized incidence ratio (SIR) of 0.89 (95% confidence interval [CI] = 0.86 to 0.92). A substantial proportion of this decreased risk was attributed to deficits of lung cancer and other smoking-related cancers. No excesses were observed for cancers of the brain or nervous system (SIR = 0.95; 95% CI = 0.81 to 1.12) or of the salivary gland (SIR = 0.72; 95% CI = 0.29 to 1.49) or for leukemia (SIR = 0.97; 95% CI = 0.78-1.21), cancers of a priori interest. Risk for these cancers also did not vary by duration of cellular telephone use, time since first subscription, age at first subscription, or type of cellular telephone (analogue or digital). Analysis of brain and nervous system tumors showed no statistically significant SIRs for any subtype or anatomic location. **CONCLUSIONS:** The results of this investigation, the first nationwide cancer incidence study of cellular phone users, do not support the hypothesis of an association between use of these telephones and tumors of the brain or salivary gland, leukemia, or other cancers.

Johansen C, Boice JD Jr, McLaughlin JK, Christensen HC, Olsen JH. Mobile phones and malignant melanoma of the eye. *Brit J Cancer* 86:348-349, 2002.

Recently a four-fold increase in the risk of malignant melanoma of the eye was associated with the use of radiofrequency transmitting devices, including mobile phones in Germany. We contrasted the incidence rates of this rare cancer with the number of mobile phone subscribers in Denmark. We observed no increasing trend in the incidence rate of melanoma, which was in sharp contrast to the exponentially increasing number of mobile phone subscribers starting in the early 1980s. Our study provides no support for an association between mobile phones and ocular melanoma.

Joubert V, Leveque P, Rametti A, Collin A, Bourthoumieu S, Yardin C. Microwave exposure of neuronal cells in vitro: Study of apoptosis. *Int J Radiat Biol.* 82(4):267-275, 2006.

Purpose:The aim of this study was to investigate microwave (MW) effects on neuronal apoptosis in vitro.**Materials and methods:**Human neuroblastoma cells SH-SY5Y were exposed to a 900 MHz global system for mobile communication (GSM) or continuous-wave (CW) radiofrequency fields for 24 h in a wire-patch cell. The specific absorption rates (SAR) used were 2 W/kg for CW and 0.25 W/kg average for GSM. During CW exposure, an increase of 2 degrees C was measured, and controls with cells exposed to 39 degrees C were then performed. Apoptosis rate was assessed immediately or 24 h after exposure using three methods: (i) 4',6-diamino-2-phenylindole (DAPI) staining; (ii) flow cytometry using double staining with TdT-mediated dUTP nick-end labeling (TUNEL) and propidium iodide (PI); and (iii) measurement of caspase-3 activity by fluorimetry.**Results:**No statistically significant difference in the apoptosis rate was observed between sham and 24 h MW-exposed cells, either GSM-900 at an average SAR of 0.25 W/kg, or CW 900 MHz at a SAR of 2 W/kg, either 0 h or 24 h post-exposure. Furthermore, for CW-exposure, apoptosis rates were comparable between sham-, CW-, 37 degrees C- and 39 degrees C-exposed cells. All three methods used to assess apoptosis were concordant.**Conclusion:**These results showed that, under the conditions of the present experiment, MW-exposure (either CW or GSM-900) does not significantly increase the apoptosis rate in the human neuroblastoma cell line SH-SY5Y.

Joubert V, Leveque P, Cueille M, Bourthoumieu S, Yardin C. No apoptosis is induced in rat cortical neurons exposed to GSM phone fields. *Bioelectromagnetics.* 2006 Sep 26; [Epub ahead of print]

The aim of this study was to investigate the radiofrequency (RF) electromagnetic fields (EMF) effects on neuronal apoptosis in vitro. Primary cultured neurons from cortices of embryonic Wistar rats were exposed to a 900-MHz global system for mobile communication (GSM) RF field for 24 h in a wire-patch cell. The average-specific absorption rate (SAR) used was 0.25 W/kg. Apoptosis rate was assessed immediately or 24 h after exposure using three methods: (i)

DAPI staining; (ii) flow cytometry using double staining with TdT-mediated dUTP nick-end labeling (TUNEL) and propidium iodide (PI); and (iii) measurement of caspase-3 activity by fluorimetry. No statistically significant difference in the apoptosis rate was observed between controls and 24 h GSM-exposed neurons, either 0 h or 24 h post-exposure. All three methods used to assess apoptosis were concordant. These results showed that, under the conditions of experiment used, GSM-exposure does not significantly increase the apoptosis rate in rat primary neuronal cultures. This work is in accordance with other studies performed on cell lines and, to our knowledge, is the first one performed on cultured cortical neurons.

Joubert V, Bourthoumieu S, Leveque P, Yardin C. Apoptosis is Induced by Radiofrequency Fields through the Caspase-Independent Mitochondrial Pathway in Cortical Neurons. *Radiat Res.* 169(1):38-45, 2008.

In the present study, we investigated whether continuous-wave (CW) radiofrequency (RF) fields induce neuron apoptosis in vitro. Rat primary neuronal cultures were exposed to a CW 900 MHz RF field with a specific absorption rate (SAR) of 2 W/kg for 24 h. During exposure, an increase of 2 degrees C was measured in the medium; control experiments with neurons exposed to 39 degrees C were then performed. Apoptosis was assessed by condensation of nuclei with 4',6-diamino-2-phenylindole (DAPI) staining observed with an epifluorescence microscope and fragmentation of DNA with TdT-mediated dUTP nick-end labeling (TUNEL) analyzed by flow cytometry. A statistically significant difference in the rate of apoptosis was found in the RF-field-exposed neurons compared to the sham-, 37 degrees C- and 39 degrees C-exposed neurons either 0 or 24 h after exposure using both methods. To assess whether the observed apoptosis was caspase-dependent or -independent, assays measuring caspase 3 activity and apoptosis-inducing factor (AIF) labeling were performed. No increase in the caspase 3 activity was found, whereas the percentage of AIF-positive nuclei in RF-field-exposed neurons was increased by three- to sevenfold compared to other conditions. Our results show that, under the experimental conditions used, exposure of primary rat neurons to CW RF fields may induce a caspase-independent pathway to apoptosis that involves AIF.

Juutilainen J, Heikkinen P, Soikkeli H, Mäki-Paakkanen J. Micronucleus frequency in erythrocytes of mice after long-term exposure to radiofrequency radiation. *Int J Radiat Biol.* 83(4):213-220, 2007.

PURPOSE: The aim of the study was to investigate genotoxicity of long-term exposure to radiofrequency (RF) electromagnetic fields by measuring micronuclei in erythrocytes. The blood samples were collected in two animal studies evaluating possible cocarcinogenic effects of RF fields. **METHODS:** In study A, female CBA/S mice were exposed for 78 weeks (1.5 h/d, 5 d/week) to either a continuous 902.5 MHz signal similar to that emitted by analog NMT (Nordic Mobile Telephone) phones at a whole-body specific absorption rate (SAR) of 1.5 W/kg, or to a pulsed 902.4 MHz signal similar to that of digital GSM (Global System for Mobile Communications) phones at 0.35 W/kg. A third group was sham-exposed, and a fourth group served as cage controls. All but the cage control animals were exposed to 4 Gy of x-rays during three first weeks of the experiment. In study B, female transgenic mice (line K2) and their nontransgenic littermates were exposed for 52 weeks (1.5 h/d, 5 d/week). Two digital mobile phone signals, GSM and DAMPS (Digital Advanced Mobile Phone System), were used at 0.5 W/kg. All but the cage-control animals were exposed 3 times per week to an ultraviolet radiation dose of 1.2 MED (minimum erythema dose). **RESULTS AND CONCLUSIONS:** The results did not show any effects of RF fields on micronucleus frequency in polychromatic or normochromatic erythrocytes. The results were consistent in two mouse strains (and in a transgenic variant of the second strain), after 52 or 78 weeks of exposure, at three SAR levels relevant to human exposure from mobile phones, and for three different mobile signals.

Kahn AA, O'Brien DF, Kelly P, Phillips JP, Rawluk D, Bolger C, Pidgeon CN. The anatomical distribution of cerebral gliomas in mobile phone users. *Ir Med J.* 96(8):240-242, 2003.

We analysed the association between mobile phone use and the anatomical distribution of glial brain tumours in Irish neurosurgical patients. All patients with unilateral histologically proven glioma were enrolled over a 12 month period. We hypothesised that were a cellular phone to cause a glioma then it would do so on the dominant hand side. Fifty mobile phone users and twenty three non-users were identified. The vast majority of patients (69/73) were right handed and the

right side of the brain was more common as the tumour site (48/73). Fisher's exact test revealed no statistical significance for glioma location based on the handedness of the patient in the mobile phone user group and location of the tumour in both user and non-user groups. We discuss our findings and the stable trend in the incidence of reported glioma cases.

Kan P, Simonsen SE, Lyon JL, Kestle JR. Cellular phone use and brain tumor: a meta-analysis. J Neurooncol. 2007 Jul 10; [Epub ahead of print]

BACKGROUND: The dramatic increase in the use of cellular phones has generated concerns about potential adverse effects, especially the development of brain tumors. We conducted a meta-analysis to examine the effect of cellular phone use on the risk of brain tumor development. **METHODS:** We searched the literature using MEDLINE to locate case-control studies on cellular phone use and brain tumors. Odds ratios (ORs) for overall effect and stratified ORs associated with specific brain tumors, long-term use, and analog/digital phones were calculated for each study using its original data. A pooled estimator of each OR was then calculated using a random-effects model. **RESULTS:** Nine case-control studies containing 5,259 cases of primary brain tumors and 12,074 controls were included. All studies reported ORs according to brain tumor subtypes, and five provided ORs on patients with ≥ 10 years of follow up. Pooled analysis showed an overall OR of 0.90 (95% confidence interval [CI] 0.81-0.99) for cellular phone use and brain tumor development. The pooled OR for long-term users of ≥ 10 years (5 studies) was 1.25 (95% CI 1.01-1.54). No increased risk was observed in analog or digital cellular phone users. **CONCLUSIONS:** We found no overall increased risk of brain tumors among cellular phone users. The potential elevated risk of brain tumors after long-term cellular phone use awaits confirmation by future studies.

Karinen A, Heinavaara S, Nylund R, Leszczynski D. Mobile phone radiation might alter protein expression in human skin. BMC Genomics. 2008 Feb 11;9(1):77 [Epub ahead of print]

ABSTRACT: BACKGROUND: Earlier we have shown that the mobile phone radiation (radiofrequency modulated electromagnetic fields; RF-EMF) alters protein expression in human endothelial cell line. This does not mean that similar response will take place in human body exposed to this radiation. Therefore, in this pilot human volunteer study, using proteomics approach, we have examined whether a local exposure of human skin to RF-EMF will cause changes in protein expression in living people. **RESULTS:** Small area of forearm's skin in 10 female volunteers was exposed to RF-EMF (specific absorption rate SAR=1.3W/kg) and punch biopsies were collected from exposed and non exposed areas of skin. Proteins extracted from biopsies were separated using 2-DE and protein expression changes were analyzed using PDQuest software. Analysis has identified 8 proteins that were statistically significantly affected (Anova and Wilcoxon tests). Two of the proteins were present in all 10 volunteers. This suggests that protein expression in human skin might be affected by the exposure to RF-EMF. The number of affected proteins was similar to the number of affected proteins observed in our earlier in vitro studies. **CONCLUSIONS:** This is the first study showing that molecular level changes might take place in human volunteers in response to exposure to RF-EMF. Our study confirms that proteomics screening approach can identify protein targets of RF-EMF in human volunteers.

Keetley V, Wood AW, Spong J, Stough C. Neuropsychological sequelae of digital mobile phone exposure in humans. Neuropsychologia. 2006 Apr 14; [Epub ahead of print]

The effect of electromagnetic fields from digital mobile phones (DMP) on cognitive functioning is an area receiving increased attention. This study compares the performance of 120 volunteers on 8 neuropsychological tests during real or sham exposure to a DMP set to maximum permissible radiofrequency power output. When results were adjusted for known covariates (gender, age, or education), several alterations at significance levels of $p < 0.05$ were obtained. Of these, simple and choice reaction times (CRT) showed strong evidence of impairment. Further, performance on the Trail Making Task (TMT) improved, supporting the hypothesis that DMP radiofrequency emissions improve the speed of processing of information held in working memory.

Kellenyi, L, Thuroczy, G, Faludy, B, Lenard, L, Effects of mobile GSM radiotelephone exposure on the auditory brainstem response (ABR). *Neurobiology* 7:79-81, 1999.

A 15-min exposure to GSM phone radiation caused an increase in auditory brainstem response in the exposed side of human subjects. Subjects also showed a hearing deficiency in the high frequency range (20 dB hearing deficiency from 2 KHz to 10 KHz).

Kerekhanjanarong V, Supivaphun P, Naratricoorn J, Laungpitackchumpon P. The effect of mobile phone to audiologic system. *J Med Assoc Thai*. 2005 Sep;88 Suppl 4:S231-234.

Mobile phones have come into widespread use. There are a lot of possible adverse effect to health. Use of mobile phone generate potentially harmful radiofrequency electromagnetic field (EMF) particularly for the hearing aspect. 98 subjects underwent hearing evaluations at Department of Otolaryngology, Faculty of Medicine, King Chulalongkorn Memorial Hospital, Chulalongkorn University. 31 males and 67 females, mean age was 30.48 +/- 9.51 years old, all subjects were investigated the hearing level by audiometry, tympanometry, otoacoustic emission (OAE) and auditory brain stem evoked response (ABR). The average of using time were 32.54 +/- 27.64 months, 57 subjects usually used the right side and 41 the left side. Average time of use per day was 26.31 +/- 30.91 minutes (range from 3 to 180 mins). When the authors compared the audiogram, both pure tone and speech audiometry, between the dominant and nondominant side, it indicated that there is no significant different. When the authors focused on the 8 subjects that used the mobile phone more than 60 mins per day. It indicated that the hearing threshold of the dominant ears was worse than the nondominant ears.

Khan MM. Adverse effects of excessive mobile phone use. *Int J Occup Med Environ Health*. 21(4):289-293, 2008.

Introduction: Research findings indicate that the use of mobile phones may lead to a number of symptoms such as headache, impaired concentration and memory, and also fatigue. Materials and Methods: The present study was designed to investigate whether the symptoms of ill health reported by young people may be associated with the use of mobile phone (MP) and to analyze its influence on health and development of medical students. The questionnaire was designed specifically for this study and contained items regarding health condition and health complaints as well as the frequency of MP use. The response rate was 86.6% (286 of 330 forms, completed by 73.77% males and 26.22% females). Results: Most of the subjects (83.57%) had some knowledge about the adverse effects of MP use. 76.92% of the students carried one mobile, and 23.08% more than one. 55.94%, of the subjects reported the average daily MP use of less than 30 min, 27.97%, of 30-60 min, 11.53%, of 60-90 min and 4.54% of more than 90 min. 16.08% of the subjects complained of headache and 24.48% of fatigue. Impaired concentration was reported by 34.27% of respondents, memory disturbances by 40.56%, sleeplessness by 38.8%, hearing problems by 23.07%, and facial dermatitis by 16.78%. The sensation of warmth within the auricle and behind/around the ear was reported by 28.32%. Out of 286 subjects who participated in this study, 44.4% related their symptoms to mobile phone use. Conclusions: The findings of the present study indicate that mobile phones play a large part in the daily life of medical students. Therefore, its impact on psychology and health should be discussed among the students to prevent the harmful effects of mobile phone use.

Khudnitskii, SS, Moshkarev, EA, Fomenko, TV, [On the evaluation of the influence of cellular phones on their users]. [Article in Russian] *Med Tr Prom Ekol* (9):20-24, 1999.

The authors studied influence of ultrahigh frequency radiation caused by cellular phones on functional state of central nervous, cardiovascular systems and local temperature changes in cellular phones users. The head area near the phone antenna appeared to be under the most intensive heating. Ultrahigh frequency radiation induces significant changes in local temperature and in physiologic parameters of central nervous and cardiovascular systems.

Kilgallon SJ, Simmons LW. Image content influences men's semen quality. *Biol Lett* 2005 (doi:10.1098/rsbl.2005.0324)

There is increasing evidence from non-human animals that males adjust their ejaculation expenditure according to the risk of sperm competition. In this study we show that, after controlling for lifestyle factors known to influence semen quality, human males viewing images depicting sperm competition had a higher percentage of motile sperm in their ejaculates. Many lifestyle variables were confirmed to influence semen quality, including the recent suggestion that storage of mobile phones close to the testes can decrease semen quality.

Kim DW, Lee JH, Ji HC, Kim SC, Nam KC, Cha EJ. Physiological effects of RF exposure on hypersensitive people by a cell phone. Conf Proc IEEE Eng Med Biol Soc. 2008;1:2322-2325.

Persons with electromagnetic hypersensitivity (EHS) complain of subjective symptoms such as headaches, insomnia, memory loss etc. resulting from radio frequency (RF) radiation by cellular phones. There have been various EHS provocation studies on heart rate, blood pressure, and subjective symptoms using GSM phones. However, there are few provocation studies on case-control study investigating simultaneously physiological parameters from CDMA phones. In this study, two volunteer groups of 18 self-declared EHS and 19 controls were exposed to both sham and real RF exposures by a CDMA cellular phone for half an hour each. We investigated the physiological parameters such as heart rates, respiration rates, and heart rate variability (HRV). In conclusion, the RF exposure by a CDMA cellular phone did not have any effects on the physiological parameters for both groups.

Kim JY, Hong SY, Lee YM, Yu SA, Koh WS, Hong JR, Son T, Chang SK, Lee M. In vitro assessment of clastogenicity of mobile-phone radiation (835 MHz) using the alkaline comet assay and chromosomal aberration test. Environ Toxicol. 23(3):319-327, 2008.

Recently we demonstrated that 835-MHz radiofrequency radiation electromagnetic fields (RF-EMF) neither affected the reverse mutation frequency nor accelerated DNA degradation in vitro. Here, two kinds of cytogenetic endpoints were further investigated on mammalian cells exposed to 835-MHz RF-EMF (the most widely used communication frequency band in Korean CDMA mobile phone networks) alone and in combination with model clastogens: in vitro alkaline comet assay and in vitro chromosome aberration (CA) test. No direct cytogenetic effect of 835-MHz RF-EMF was found in the in vitro CA test. The combined exposure of the cells to RF-EMF in the presence of ethylmethanesulfonate (EMS) revealed a weak and insignificant cytogenetic effect when compared to cells exposed to EMS alone in CA test. Also, the comet assay results to evaluate the ability of RF-EMF alone to damage DNA were nearly negative, although showing a small increase in tail moment. However, the applied RF-EMF had potentiation effect in comet assay when administered in combination with model clastogens (cyclophosphamide or 4-nitroquinoline 1-oxide). Thus, our results imply that we cannot confidently exclude any possibility of an increased risk of genetic damage, with important implications for the possible health effects of exposure to 835-MHz electromagnetic fields.

Kimata H. Enhancement of allergic skin wheal responses by microwave radiation from mobile phones in patients with atopic eczema/dermatitis syndrome. *Int Arch Allergy Immunol* 129(4):348-350, 2002.

Microwave radiation from mobile phones enhanced skin wheal responses induced by house dust mite and Japanese cedar pollen while it had no effect on wheal responses induced by histamine in patients with atopic eczema/dermatitis syndrome (AEDS). Microwave radiation also increased plasma levels of substance P (SP) and vasoactive intestinal peptide (VIP) in patients with AEDS. These results indicate that microwave radiation from mobile phones may enhance allergen-induced wheal responses in association with the release of SP and VIP. This finding may be useful in elucidating the pathophysiology and treatment of AEDS.

Kimata H. Microwave radiation from cellular phones increases allergen-specific IgE production. *Allergy* 60(6):838-839, 2005.

Kizilay A, Ozturan O, Erdem T, Tayyar Kalcioğlu M, Cem Miman M. Effects of chronic exposure of electromagnetic fields from mobile phones on hearing in rats. *Auris Nasus Larynx*. 30(3):239-245, 2003.

OBJECTIVE: Little attention has been paid to the effects of electromagnetic field (EMF) of mobile phones on hearing. The aim of this study is to investigate the effects of chronic exposure to EMF emitting from mobile phones on the inner ear of adult and developing rats using distortion product otoacoustic emissions (DPOAEs). **METHODS:** EMF of mobile phones exposure was scheduled according to a sham-exposure controlled experimental design. Every day seven of 14 adult and four newborn rats were exposed to 1-h mobile phone EMF for 30 days, while the other seven adult rats were assigned to control group. DPOAEs were measured in both groups before and after the chronic exposure to EMF. The

newborn rats were tested following similar exposure beginning on the 2nd day after birth. RESULTS: No measurable EMF associated changes in DPOAEs either in adult or developing rat inner ears were determined ($P>0.05$).

CONCLUSION: It was concluded that chronic exposure of EMF, as long as 30 days 1 h per day, emitting from a mobile phone did not cause any hearing deterioration in adult and developing rats, at least at outer and middle ear and cochlear levels.

Klaeboe L, Blaasaas KG, Tynes T. Use of mobile phones in Norway and risk of intracranial tumours. *Eur J Cancer Prev.* 16(2):158-164, 2007.

To test the hypothesis that exposure to radio-frequency electromagnetic fields from mobile phones increases the incidence of gliomas, meningiomas and acoustic neuromas in adults. The incident cases were of patients aged 19-69 years who were diagnosed during 2001-2002 in Southern Norway. Population controls were selected and frequency-matched for age, sex, and residential area. Detailed information about mobile phone use was collected from 289 glioma (response rate 77%), 207 meningioma patients (71%), and 45 acoustic neuroma patients (68%) and from 358 (69%) controls. For regular mobile phone use, defined as use on average at least once a week or more for at least 6 months, the odds ratio was 0.6 (95% confidence interval 0.4-0.9) for gliomas, 0.8 (95% confidence interval 0.5-1.1) for meningiomas and 0.5 (95% confidence interval 0.2-1.0) for acoustic neuromas. Similar results were found with mobile phone use for 6 years or more for gliomas and acoustic neuromas. An exception was meningiomas, where the odds ratio was 1.2 (95% confidence interval 0.6-2.2). Furthermore, no increasing trend was observed for gliomas or acoustic neuromas by increasing duration of regular use, the time since first regular use or cumulative use of mobile phones. The results from the present study indicate that use of mobile phones is not associated with an increased risk of gliomas, meningiomas or acoustic neuromas.

Kleinlogel H, Dierks T, Koenig T, Lehmann H, Minder A, Berz R. Effects of weak mobile Phone-Electromagnetic fields (GSM, UMTS) on well-being and resting EEG. *Bioelectromagnetics.* 29(6): 479-487, 2008.

Modern mobile phones emit electromagnetic fields (EMFs) ranging from 900 to 2000 MHz which are suggested to have an influence on well-being, attention and neurological parameters in mobile phone users. To date most studies have investigated Global System for Mobile Communications (GSM)-EMF and only very few studies were concerned with Universal Mobile Telecommunications System (UMTS)-EMF. Consequently, we tested the effects of both types of EMF, 1950 MHz UMTS (SAR 0.1 and 1 W/kg) and pulsed 900 MHz GSM (1 W/kg), on well-being and vigilance-controlled resting electroencephalogram (eyes closed) in 15 healthy, right-handed subjects. A double-blind, randomised, crossover application of the test procedure was used. Neither the UMTS- nor the GSM-EMF produced any significant changes in the measured parameters compared to sham exposure. The results do not give any evidence for a deleterious effect of the EMF on normal healthy mobile phone users.

Kleinlogel H, Dierks T, Koenig T, Lehmann H, Minder A, Berz R. Effects of weak mobile phone - electromagnetic fields (GSM, UMTS) on event related potentials and cognitive functions. *Bioelectromagnetics.* 29(6):488-497, 2008.

Modern mobile phones emit electromagnetic fields (EMF) ranging from 900 to 2000 MHz which are suggested to have an influence on well-being, attention and neurological parameters in mobile phone users. Until now most studies have investigated Global System for Mobile Communications (GSM)-EMF and only very few studies have focused on Universal Mobile Telecommunications System (UMTS)-EMF. Therefore, we tested the effects of both types of unilaterally presented EMF, 1950 UMTS (0.1 and 1 W/kg) and pulsed 900 MHz GSM (1 W/kg), on visually evoked occipital P100, the P300 of a continuous performance test, auditory evoked central N100 and the P300 during an oddball task as well as on the respective behavioral parameters, reaction time and false reactions, in 15 healthy, right handed subjects. A double-blind, randomized, crossover application of the test procedure was used. Neither the UMTS- nor the GSM-EMF produced any significant changes in the measured parameters compared to sham exposure. The results do not give any evidence for a deleterious effect of the EMF on normal healthy mobile phone users.

Koivisto, M, Revonsuo, A, Krause, C, Haarala, C, Sillanmaki, L, Laine, M, Hamalainen, H, Effects of 902 MHz electromagnetic field emitted by cellular telephones on response times in humans. *Neuroreport* 11(2):413-415, 2000.

The present study examined possible influences of a 902 MHz electromagnetic field emitted by cellular telephones on cognitive functioning in 48 healthy humans. A battery of 12 reaction time tasks was performed twice by each participant

in a counterbalanced order: once with and once without the exposure to the field. The results showed that the exposure to the electromagnetic field speeded up response times in simple reaction time and vigilance tasks and that the cognitive time needed in a mental arithmetics task was decreased. The results suggest that exposure to the electromagnetic field emitted by cellular telephones may have a facilitatory effect on brain functioning, especially in tasks requiring attention and manipulation of information in working memory.

Koivisto M, Krause CM, Revonsuo A, Laine M, Hamalainen H, The effects of electromagnetic field emitted by GSM phones on working memory. *Neuroreport* 11(8):1641-1643, 2000.

The influence of pulsed radiofrequency (RF) electromagnetic fields of digital GSM mobile phones on working memory in healthy subjects were studied. Memory load was varied from 0 to 3 items in an n-back task. Each subject was tested twice within a single session, with and without the RF exposure (902MHz, 217Hz). The RF field speeded up response times when the memory load was three items but no effects of RF were observed with lower loads. The results suggest that RF fields have a measurable effect on human cognitive performance and encourage further studies on the interactions of RF fields with brain function.

Koivisto M, Haarala C, Krause CM, Revonsuo A, Laine M, Hamalainen H, GSM phone signal does not produce subjective symptoms. *Bioelectromagnetics* 22(3):212-215, 2001.

The influence of pulsed radiofrequency (RF) electromagnetic fields of digital GSM mobile phones (902 MHz, 217 Hz pulse modulation) on subjective symptoms or sensations in healthy subjects were studied in two single-blind experiments. The duration of the RF exposure was about 60 min in Experiment 1 and 30 min in Experiment 2. Each subject rated symptoms or sensations in the beginning of the experimental session and at the end of both the exposure and the nonexposure conditions. The symptoms rated were headache, dizziness, fatigue, itching or tingling of the skin, redness on the skin, and sensations of warmth on the skin. The results did not reveal any differences between exposure and non-exposure conditions, suggesting that a 30-60 min exposure to this RF field does not produce subjective symptoms in humans.

Koylu H, Mollaoglu H, Ozguner F, Nazyroglu M, Delibab N. Melatonin modulates 900 Mhz microwave-induced lipid peroxidation changes in rat brain. *Toxicol Ind Health*. 22(5):211-216, 2006.

Microwaves (MW) from cellular phones may affect biological systems by increasing free radicals, which may enhance lipid peroxidation levels of the brain, thus leading to oxidative damage. Melatonin is synthesized in and secreted by the pineal gland at night and exhibits anti-oxidant properties. Several studies suggest that supplementation with anti-oxidant can influence MW-induced brain damage. The present study was designed to determine the effects of MW on the brain lipid peroxidation system, and the possible protective effects of melatonin on brain degeneration induced by MW. Twenty-eight Sprague-Dawley male rats were randomly divided into three groups as follows: (1) sham-operated control group (N = 8); (2) study 900-MHz MW-exposed group (N = 8); and (3) 900-MHz MW-exposed+melatonin (100 microg/kg sc before daily MW exposure treated group) (N = 10). Cortex brain and hippocampus tissues were removed to study the levels of lipid peroxidation as malonyl dialdehyde. The levels of lipid peroxidation in the brain cortex and hippocampus increased in the MW group compared with the control group, although the levels in the hippocampus were decreased by MW+melatonin administration. The brain cortex lipid peroxidation levels were unaffected by melatonin treatment. We conclude that melatonin may prevent MW-induced oxidative changes in the hippocampus by streng

Koyu A, Ozguner F, Cesur G, Gokalp O, Mollaoglu H, Caliskan S, Delibas N. No effects of 900 MHz and 1800 MHz electromagnetic field emitted from cellular phone on nocturnal serum melatonin levels in rats. *Toxicol Ind Health*. 21(1-2):27-31, 2005a.

In this study, the effects of exposure to a 900 MHz and 1800 MHz electromagnetic field (EMF) on serum nocturnal melatonin levels of adult male Sprague-Dawley rats were studied. Thirty rats were used in three independent groups, 10 of which were exposed to 900 MHz, 10 of which were exposed to 1800 MHz and 10 of which were sham-exposed (control). The exposures were performed 30 min/day, for five days/week for four weeks to 900 MHz or 1800 MHz EMF Control animals were kept under the same environmental conditions as the study groups except with no EMF exposure. The concentration of nocturnal melatonin in the rat serum was measured by using a radioimmunoassay method. There were no statistically significant differences in serum melatonin concentrations between the 900 MHz EMF group and the sham-

exposed group ($P > 0.05$). The values at 12:00 pm were 39.11 ± 6.5 pg/mL in the sham-exposed group and 34.97 ± 5.1 pg/mL in the 900 MHz EMF-exposed group. Also, there were no statistically significant differences in serum melatonin concentrations between the sham-exposed group and the 1800 MHz EMF-exposed group ($P > 0.05$). The values at 12:00 pm were 39.11 ± 6.5 pg/mL in the sham-exposed group and 37.96 ± 7.4 pg/mL in the exposed group. These results indicate that mobile phones, emitting 900 and 1800 MHz EMF, have no effect on nocturnal serum melatonin levels in rats.

Koyu A, Cesur G, Ozguner F, Akdogan M, Mollaoglu H, Ozen S. Effects of 900MHz electromagnetic field on TSH and thyroid hormones in rats. *Toxicol Lett.* 157(3):257-262, 2005b.

In this study, the effects of exposure to a 900megahertz (MHz) electromagnetic field (EMF) on serum thyroid stimulating hormone (TSH) and triiodothyronine-thyroxine (T(3)-T(4)) hormones levels of adult male Sprague-Dawley rats were studied. Thirty rats were used in three independent groups, 10 of which were control (without stress and EMF), 10 of which were exposed to 900MHz EMF and 10 of which were sham-exposed. The exposures were performed 30min/day, for 5days/week for 4 weeks to 900MHz EMF. Sham-exposed animals were kept under the same environmental conditions as the study groups except with no EMF exposure. The concentration of TSH and T(3)-T(4) hormones in the rat serum was measured by using an immunoradiometric assay (IRMA) method for TSH and a radio-immunoassay (RIA) method for T(3) and T(4) hormones. TSH values and T(3)-T(4) at the 900MHz EMF group were significantly lower than the sham-exposed group ($p < 0.01$). There were no statistically significant differences in serum TSH values and T(3)-T(4) hormone concentrations between the control and the sham-exposed group ($p > 0.05$). These results indicate that 900MHz EMF emitted by cellular telephones decrease serum TSH and T(3)-T(4) levels.

Kramarenko AV, Tan U. EFFECTS OF HIGH-FREQUENCY ELECTROMAGNETIC FIELDS ON HUMAN EEG: A BRAIN MAPPING STUDY. *Int J Neurosci.* 113(7):1007-1019, 2003.

Cell phones emitting pulsed high-frequency electromagnetic fields (EMF) may affect the human brain, but there are inconsistent results concerning their effects on electroencephalogram (EEG). We used a 16-channel telemetric electroencephalograph (ExpertTM), to record EEG changes during exposure of human skull to EMF emitted by a mobile phone. Spatial distribution of EMF was especially concentrated around the ipsilateral eye adjacent to the basal surface of the brain. Traditional EEG was full of noises during operation of a cellular phone. Using a telemetric electroencephalograph (ExpertTM) in awake subjects, all the noise was eliminated, and EEG showed interesting changes: after a period of 10-15 s there was no visible change, the spectrum median frequency increased in areas close to antenna; after 20-40 s, a slow-wave activity (2.5-6.0 Hz) appeared in the contralateral frontal and temporal areas. These slow waves lasting for about one second repeated every 15-20 s at the same recording electrodes. After turning off the mobile phone, slow-wave activity progressively disappeared; local changes such as increased median frequency decreased and disappeared after 15-20 min. We observed similar changes in children, but the slow-waves with higher amplitude appeared earlier in children (10-20 s) than adults, and their frequency was lower (1.0-2.5 Hz) with longer duration and shorter intervals. The results suggested that cellular phones may reversibly influence the human brain, inducing abnormal slow waves in EEG of awake persons.

Krause CM, Sillanmaki L, Koivisto M, Haggqvist A, Saarela C, Revonsuo A, Laine M, Hamalainen H, Effects of electromagnetic field emitted by cellular phones on the EEG during a memory task. *Neuroreport* 11(4):761-764, 2000.

The effects of electromagnetic fields (EMF) emitted by cellular phones on the ERD/ERS of the 4-6 Hz, 6-8 Hz, 8-10 Hz and 10-12 Hz EEG frequency bands were studied in 16 normal subjects performing an auditory memory task. All subjects performed the memory task both with and without exposure to a digital 902 MHz EMF in counterbalanced order. The exposure to EMF significantly increased EEG power in the 8-10 Hz frequency band only. Nonetheless, the presence of EMF altered the ERD/ERS responses in all studied frequency bands as a function of time and memory task (encoding vs retrieval). Our results suggest that the exposure to EMF does not alter the resting EEG per se but modifies the brain responses significantly during a memory task.

Krause CM, Sillanmaki L, Koivisto M, Haggqvist A, Saarela C, Revonsuo A, Laine M, Hamalainen H, Effects of electromagnetic fields emitted by cellular phones on the electroencephalogram during a visual working memory task. *Int J Radiat Biol* 76(12):1659-1667, 2000.

PURPOSE: To examine the effects of electromagnetic fields (EMF) emitted by cellular phones on the event-related desynchronization/synchronization (ERD/ERS) responses of the 4-6, 6-8, 8-10 and 10-12Hz EEG frequency bands during cognitive processing. **MATERIALS AND METHODS:** Twenty-four subjects performed a visual sequential letter task (n-back task) with three different working memory load conditions: zero, one and two items. All subjects performed the memory task both with and without exposure to a digital 902 MHz EMF in counterbalanced order. **RESULTS:** The presence of EMF altered the ERD/ERS responses in the 6-8 and 8-10 Hz frequency bands but only when examined as a function of memory load and depending also on whether the presented stimulus was a target or not. **CONCLUSIONS:** The results suggest that the exposure to EMF modulates the responses of EEG oscillatory activity approximately 8 Hz specifically during cognitive processes.

Krause CM, Haarala C, Sillanmaki L, Koivisto M, Alanko K, Revonsuo A, Laine M, Hamalainen H. Effects of electromagnetic field emitted by cellular phones on the EEG during an auditory memory task: a double blind replication study. *Bioelectromagnetics*. 25(1): 33-40, 2004.

The effects of electromagnetic fields (EMF) emitted by cellular phones on the event related desynchronization/synchronization (ERD/ERS) of the 4-6, 6-8, 8-10, and 10-12 Hz electroencephalogram (EEG) frequency bands were studied in 24 normal subjects performing an auditory memory task. This study was a systematic replication of our previous work. In the present double blind study, all subjects performed the memory task both with and without exposure to a digital 902 MHz field in a counterbalanced order. We were not able to replicate the findings from our earlier study. All eight of the significant changes in our earlier study were not significant in the present double blind replication. Also, the effect of EMF on the number of incorrect answers in the memory task was inconsistent. We previously reported no significant effect of EMF exposure on the number of incorrect answers in the memory task, but a significant increase in errors was observed in the present study. We conclude that EMF effects on the EEG and on the performance on memory tasks may be variable and not easily replicable for unknown reasons.

Krause CM, Bjornberg CH, Pesonen M, Hulten A, Liesivuori T, Koivisto M, Revonsuo A, Laine M, Hamalainen H. Mobile phone effects on children's event-related oscillatory EEG during an auditory memory task. *Int J Radiat Biol*. 82(6):443-450, 2006.

Purpose: To assess the effects of electromagnetic fields (EMF) emitted by mobile phones (MP) on the 1 - 20 Hz event-related brain oscillatory EEG (electroencephalogram) responses in children performing an auditory memory task (encoding and recognition). **Materials and methods:** EEG data were gathered while 15 subjects (age 10 - 14 years) performed an auditory memory task both with and without exposure to a digital 902 MHz MP in counterbalanced order. **Results:** During memory encoding, the active MP modulated the event-related desynchronization/synchronization (ERD/ERS) responses in the approximately 4 - 8 Hz EEG frequencies. During recognition, the active MP transformed these brain oscillatory responses in the approximately 4 - 8 Hz and approximately 15 Hz frequencies. **Conclusions:** The current findings suggest that EMF emitted by mobile phones has effects on brain oscillatory responses during cognitive processing in children.

Krause CM, Pesonen M, Haarala Bjornberg C, Hamalainen H. Effects of pulsed and continuous wave 902 MHz mobile phone exposure on brain oscillatory activity during cognitive processing. *Bioelectromagnetics*. 2007 Jan 3; [Epub ahead of print]

The aim of the current double-blind studies was to partially replicate the studies by Krause et al. [2000ab, 2004] and to further investigate the possible effects of electromagnetic fields (EMF) emitted by mobile phones (MP) on the event-related desynchronisation/synchronisation (ERD/ERS) EEG (electroencephalogram) responses during cognitive processing. Two groups, both consisting of 36 male participants, were recruited. One group performed an auditory

memory task and the other performed a visual working memory task in six exposure conditions: SHAM (no EMF), CW (continuous wave EMF) and PM (pulse modulated EMF) during both left- and right-side exposure, while the EEG was recorded. In line with our previous studies, we observed that the exposure to EMF had modest effects on brain oscillatory responses in the alpha frequency range (approximately 8-12 Hz) and had no effects on the behavioural measures. The effects on the EEG were, however, varying, unsystematic and inconsistent with previous reports. We conclude that the effects of EMF on brain oscillatory responses may be subtle, variable and difficult to replicate for unknown reasons.

Kumlin T, Iivonen H, Miettinen P, Juvonen A, van Groen T, Puranen L, Pitkäaho R, Juutilainen J, Tanila H. Mobile phone radiation and the developing brain: behavioral and morphological effects in juvenile rats. *Radiat Res.* 168(4):471-479, 2007.

The increasing use of mobile phones by children and teenagers has raised concerns about their safety. Addressing such concerns is difficult, because no data are available on possible effects from long-term exposure to radiofrequency (RF) fields during the development of the nervous system. Possible morphological and functional changes were evaluated in the central nervous system of young male Wistar rats exposed to 900 MHz mobile phone signal for 2 h/day on 5 days/week. After 5 weeks of exposure at whole-body average specific energy absorption rates of 0.3 or 3.0 W/kg or sham exposure, six rats per group were examined histologically, and the remaining 18 rats per group were subjected to behavioral tests. No degenerative changes, dying neurons, or effects on the leakage of the blood-brain barrier were detected. No group differences were observed in the open-field test, plus maze test or acoustic startle response tests. In the water maze test, however, significantly improved learning ($P = 0.012$) and memory ($P = 0.01$) were detected in rats exposed to RF fields. The results do not indicate a serious threat to the developing brain from mobile phone radiation at intensities relevant to human exposure. However, the interesting finding of improved learning and memory warrants further studies.

Kuribayashi M, Wang J, Fujiwara O, Doi Y, Nabae K, Tamano S, Ogiso T, Asamoto M, Shirai T. Lack of effects of 1439 MHz electromagnetic near field exposure on the blood-brain barrier in immature and young rats. *Bioelectromagnetics.* 2005 Sep 2; [Epub ahead of print]

Possible effects of 1439 MHz electromagnetic near field (EMF) exposure on the blood-brain barrier (BBB) were investigated using immature (4 weeks old) and young (10 weeks old) rats, equivalent in age to the time when the BBB development is completed and the young adult, respectively. Alteration of BBB related genes, such as those encoding p-glycoprotein, aquaporin-4, and claudin-5, was assessed at the protein and mRNA levels in the brain after local exposure of the head to EMF at 0, 2, and 6 W/kg specific energy absorption rates (SARs) for 90 min/day for 1 or 2 weeks. Although expression of the 3 genes was clearly decreased after administration of 1,3-dinitrobenzene (DNB) as a positive control, when compared with the control values, there were no pathologically relevant differences with the EMF at any exposure levels at either age. Vascular permeability, monitored with reference to transfer of FITC-dextran, FD20, was not affected by EMF exposure. Thus, these findings suggest that local exposure of the head to 1439 MHz EMF exerts no adverse effects on the BBB in immature and young rats.

Kwee S, Raskmark P. Changes in cell proliferation due to environmental non-ionizing radiation 2. Microwave radiation. *Bioelectrochem Bioenerg* 44(2) 251-255, 1998.

Due to the use of mobile telephones, there is an increased exposure of the environment to weak radiofrequency (RF) electromagnetic fields, emitted by these devices. This study was undertaken to investigate if the microwave radiation from these fields will have a similar effect on cell proliferation as weak electromagnetic (ELF) fields. The field was generated by signal simulation of the Global System for Mobile communications (GSM) of 960 MHz. Cell cultures, growing in microtiter plates, were exposed in a specially constructed chamber, a Transverse Electromagnetic (TEM) cell. The Specific Absorption Rate (SAR) values for each cell well were calculated for this exposure system. Experiments were performed on cell cultures of transformed human epithelial amnion cells (AMA), which were exposed to 960 MHz microwave fields at three different power levels and three different exposure times, respectively. It was found that cell growth in the exposed cells was decreased in comparison to that in the control and sham exposed cells. Cell proliferation during the period following exposure varied not only with the various SAR levels, but also with the length of exposure

time. On the other hand, repeated periods of exposure did not seem to change the effects. There was a general linear correlation between power level and growth change. However, the exposure time required to obtain the maximum effect was not the same for the various power levels. It turned out that at low power level, a maximum effect was first reached after a longer exposure time than at higher power level. A similar phenomenon was registered in the studies on ELF electromagnetic fields. Here, it was found that there was a linear correlation between the length of exposure time to obtain maximum effect and field strength.

Kwee S, Raskmark P, Velizarov P. Changes in cellular proteins due to environmental non-ionizing radiation. I. Heat-shock proteins. *Electro- and Magnetobiology* 20: 141-152, 2001.

This paper describes the effect of weak microwave fields on the amounts of heat-shock proteins in cell cultures at various temperatures. The field was generated by signal simulation of the Global System for Mobile communications (GSM) of 960 Mhz, used in portable phones. Transformed human epithelial amnion (AMA) cells, growing on glass coverslips, were exposed in a transverse electromagnetic (TEM) cell to a microwave field, generating a specific absorption rate (SAR) of $2.1 \text{ mW} \cdot \text{kg}^{-1}$ in the cells. Exposure temperatures were 35, 37, and $40 \pm 0.1^\circ\text{C}$, respectively, and the exposure time was 20 min. The heat-shock proteins Hsp-70 and Hsp-27 were detected by immuno-fluorescence. Higher amounts of Hsp-70 were present in the cells exposed at 35 and 37°C than in the sham-exposed cells. These effects can be considered to be athermal, since the field strength was much lower than the safety standard for absence of heat generation by microwave fields. There was no significant response in the case of Hsp-27.

Kwon MS, Kujala T, Huotilainen M, Shestakova A, Näätänen R, Hämäläinen H. Preattentive auditory information processing under exposure to the 902 MHz GSM mobile phone electromagnetic field: A mismatch negativity (MMN) study. *Bioelectromagnetics*. 2009 Jan 12. [Epub ahead of print]

Previous studies on the effects of the mobile phone electromagnetic field (EMF) on various event-related potential (ERP) components have yielded inconsistent and even contradictory results, and often failed in replication. The mismatch negativity (MMN) is an auditory ERP component elicited by infrequent (deviant) stimuli differing in some physical features from the repetitive frequent (standard) stimuli in a sound sequence. The MMN provides a sensitive measure for cortical auditory stimulus feature discrimination, regardless of attention and other contaminating factors. In this study, MMN responses to duration, intensity, frequency, and gap changes were recorded in healthy young adults ($n = 17$), using a multifeature paradigm including several types of auditory change in the same stimulus sequence, while a GSM mobile phone was placed on either ear with the EMF (902 MHz pulsed at 217 Hz; $\text{SAR}(1\text{g}) = 1.14 \text{ W/kg}$, $\text{SAR}(10\text{g}) = 0.82 \text{ W/kg}$, peak value = 1.21 W/kg , measured with an SAM phantom) on or off. An MMN was elicited by all deviant types, while its amplitude and latency showed no significant differences due to EMF exposure for any deviant types. In the present study, we found no conclusive evidence that acute exposure to GSM mobile phone EMF affects cortical auditory change detection processing reflected by the MMN.

La Regina M, Moros EG, Pickard WF, Straube WL, Baty J, Roti Roti JL. The Effect of Chronic Exposure to 835.62 MHz FDMA or 847.74 MHz CDMA Radiofrequency Radiation on the Incidence of Spontaneous Tumors in Rats. *Radiat Res*. 160(2):143-151, 2003.

This study was designed to determine whether chronic exposure to radiofrequency (RF) radiation from cellular phones increased the incidence of spontaneous tumors in F344 rats. Eighty male and 80 female rats were randomly placed in each of three irradiation groups. The sham group received no irradiation; the Frequency Division Multiple Access (FDMA) group was exposed to 835.62 MHz FDMA RF radiation; and the Code Division Multiple Access (CDMA) group was exposed to 847.74 MHz CDMA RF radiation. Rats were irradiated 4 h per day, 5 days per week over 2 years. The nominal time-averaged specific absorption rate (SAR) in the brain for the irradiated animals was $0.85 \pm 0.34 \text{ W/kg}$ (mean \pm SD) per time-averaged watt of antenna power. Antennas were driven with a time-averaged power of $1.50 \pm 0.25 \text{ W}$ (range). That is, the nominal time-averaged brain SAR was $1.3 \pm 0.5 \text{ W/kg}$ (mean \pm SD). This number was an average from several measurement locations inside the brain, and it takes into account changes in animal weight and head position during irradiation. All major organs were evaluated grossly and histologically. The number of tumors, tumor types and incidence of hyperplasia for each organ were recorded. There were no significant differences among final body

weights or survival days for either males or females in any group. No significant differences were found between treated and sham-exposed animals for any tumor in any organ. We conclude that chronic exposure to 835.62 MHz FDMA or 847.74 MHz CDMA RF radiation had no significant effect on the incidence of spontaneous tumors in F344 rats.

Lahkola A, Auvinen A, Raitanen J, Schoemaker MJ, Christensen HC, Feychting M, Johansen C, Klæboe L, Lönn S, Swerdlow AJ, Tynes T, Salminen T. Mobile phone use and risk of glioma in 5 North European countries. *Int J Cancer*. 2007 Jan 17; [Epub ahead of print]

Public concern has been expressed about the possible adverse health effects of mobile telephones, mainly related to intracranial tumors. We conducted a population-based case-control study to investigate the relationship between mobile phone use and risk of glioma among 1,522 glioma patients and 3,301 controls. We found no evidence of increased risk of glioma related to regular mobile phone use (odds ratio, OR = 0.78, 95% confidence interval, CI: 0.68, 0.91). No significant association was found across categories with duration of use, years since first use, cumulative number of calls or cumulative hours of use. When the linear trend was examined, the OR for cumulative hours of mobile phone use was 1.006 (1.002, 1.010) per 100 hr, but no such relationship was found for the years of use or the number of calls. We found no increased risks when analogue and digital phones were analyzed separately. For more than 10 years of mobile phone use reported on the side of the head where the tumor was located, an increased OR of borderline statistical significance (OR = 1.39, 95% CI 1.01, 1.92, p trend 0.04) was found, whereas similar use on the opposite side of the head resulted in an OR of 0.98 (95% CI 0.71, 1.37). Although our results overall do not indicate an increased risk of glioma in relation to mobile phone use, the possible risk in the most heavily exposed part of the brain with long-term use needs to be explored further before firm conclusions can be drawn.

Lahkola A, Salminen T, Raitanen J, Heinävaara S, Schoemaker M, Christensen HC, Feychting M, Johansen C, Klæboe L, Lönn S, Swerdlow A, Tynes T, Auvinen A. Meningioma and mobile phone use--a collaborative case-control study in five North European countries. *Int J Epidemiol*. 2008 Aug 2. [Epub ahead of print]

BACKGROUND: Use of mobile telephones has been suggested as a possible risk factor for intracranial tumours. To evaluate the effect of mobile phones on risk of meningioma, we carried out an international, collaborative case-control study of 1209 meningioma cases and 3299 population-based controls. METHODS: Population-based cases were identified, mostly from hospitals, and controls from national population registers and general practitioners' patient lists. Detailed history of mobile phone use was obtained by personal interview. Regular mobile phone use (at least once a week for at least 6 months), duration of use, cumulative number and hours of use, and several other indicators of mobile phone use were assessed in relation to meningioma risk using conditional logistic regression with strata defined by age, sex, country and region. RESULTS: Risk of meningioma among regular users of mobile phones was apparently lower than among never or non-regular users (odds ratio, OR = 0.76, 95% confidence interval, CI 0.65, 0.89). The risk was not increased in relation to years since first use, lifetime years of use, cumulative hours of use or cumulative number of calls. The findings were similar regardless of telephone network type (analogue/digital), age or sex. CONCLUSIONS: Our results do not provide support for an association between mobile phone use and risk of meningioma.

Langer P, Holzner B, Magnet W, Kopp M. Hands-free mobile phone conversation impairs the peripheral visual system to an extent comparable to an alcohol level of 4-5 g 100 ml. *Hum Psychopharmacol*. 20(1):65-66, 2005.

Lantow M, Schuderer J, Hartwig C, Simko M. Free Radical Release and HSP70 Expression in Two Human Immune-Relevant Cell Lines after Exposure to 1800 MHz Radiofrequency Radiation. *Radiat Res*. 165(1):88-94, 2006a.

The goal of this study was to investigate whether radiofrequency (RF) electromagnetic-field (EMF) exposure at 1800 MHz causes production of free radicals and/or expression of heat-shock proteins (HSP70) in human immune-relevant cell systems. Human Mono Mac 6 and K562 cells were used to examine free radical release after exposure to incubator control, sham, RF EMFs, PMA, LPS, heat (40 degrees C) or co-exposure conditions. Several signals were used:

continuous-wave, several typical modulations of the Global System for Mobile Communications (GSM): GSM-non DTX (speaking only), GSM-DTX (hearing only), GSM-Talk (34% speaking and 66% hearing) at specific absorption rates (SARs) of 0.5, 1.0, 1.5 and 2.0 W/kg. Heat and PMA treatment induced a significant increase in superoxide radical anions and in ROS production in the Mono Mac 6 cells when compared to sham and/ or incubator conditions. No significant differences in free radical production were detected after RF EMF exposure or in the respective controls, and no additional effects on superoxide radical anion production were detected after co-exposure to RF EMFs+PMA or RF EMFs+LPS. The GSM-DTX signal at 2 W/kg produced a significant difference in free radical production when the data were compared to sham because of the decreasing sham value. This difference disappeared when data were compared to the incubator controls. To determine the involvement of heat-shock proteins as a possible inhibitor of free radical production, we investigated the HSP70 expression level after different RF EMF exposures; no significant effects were detected.

Lantow M, Lupke M, Frahm J, Mattsson MO, Kuster N, Simko M.

ROS release and Hsp70 expression after exposure to 1,800 MHz radiofrequency electromagnetic fields in primary human monocytes and lymphocytes. Radiat Environ Biophys. 2006b Mar 22; [Epub ahead of print]

The aim of this study is to investigate if 1,800 MHz radiofrequency electromagnetic fields (RF-EMF) can induce reactive oxygen species (ROS) release and/or changes in heat shock protein 70 (Hsp70) expression in human blood cells, using different exposure and co-exposure conditions. Human umbilical cord blood-derived monocytes and lymphocytes were used to examine ROS release after exposure to continuous wave or different GSM signals (GSM-DTX and GSM-Talk) at 2 W/kg for 30 or 45 min of continuous or intermittent (5 min ON/5 min OFF) exposure. The cells were exposed to incubator conditions, to sham, to RF-EMF, or to chemicals in parallel. Cell stimulation with the phorbol ester phorbol-12-myristate-13-acetate (PMA; 1 μ M) was used as positive control for ROS release. To investigate the effects on Hsp70 expression, the human monocytes were exposed to the GSM-DTX signal at 2 W/kg for 45 min, or to heat treatment (42 degrees C) as positive control. ROS production and Hsp70 expression were determined by flow cytometric analysis. The data were compared to sham and/or to control values and the statistical analysis was performed by the Student's t-test ($P < 0.05$). The PMA treatment induced a significant increase in ROS production in human monocytes and lymphocytes when the data were compared to sham or to incubator controls. After continuous or intermittent GSM-DTX signal exposure (2 W/kg), a significantly different ROS production was detected in human monocytes if the data were compared to sham. However, this significant difference appeared due to the lowered value of ROS release during sham exposure. In human lymphocytes, no differences could be detected if data were compared either to sham or to incubator control. The Hsp70 expression level after 0, 1, and 2 h post-exposure to GSM-DTX signal at 2 W/kg for 1 h did not show any differences compared to the incubator or to sham control.

Lantow, M., Viergutz, T., Weiss, D. G. and Simko, M. Comparative Study of Cell Cycle Kinetics and Induction of Apoptosis or Necrosis after Exposure of Human Mono Mac 6 Cells to Radiofrequency Radiation. *Radiat. Res.* 166, 539-543 2006.

The possible harmful effects of radiofrequency electromagnetic fields (RF EMFs) are controversial. We have used human Mono Mac 6 cells to investigate the influence of RF EMFs in vitro on cell cycle alterations and BrdU uptake, as well as the induction of apoptosis and necrosis in human Mono Mac 6 cells, using flow cytometry after exposure to a 1800 MHz, 2 W/kg specific absorption rate (SAR), GSM-DTX signal for 12 h. No statistically significant differences in the induction of apoptosis or necrosis, cell cycle kinetics, or BrdU uptake were detected after RF EMF exposure compared to sham or incubator controls. However, in the positive control cells treated with gliotoxin and PMA (phorbol 12 myristate-13 acetate), a significant increase in apoptotic and necrotic cells was seen. Cell cycle analysis or BrdU incorporation for 72 h showed no differences between RF EMF- or sham-exposed cells, whereas PMA treatment induced a significant accumulation of cells in G(0)/G(1)-phase and a reduction in S-phase cells. RF EMF radiation did not induce cell cycle alterations or changes in BrdU incorporation or induce apoptosis and necrosis in Mono Mac 6 cells under the exposure conditions used.

Laszlo, A., Moros, E. G., Davidson, T., Bradbury, M., Straube, W. and Roti Roti, J. The Heat-Shock Factor is not Activated in Mammalian Cells Exposed to Cellular Phone Frequency Microwaves. *Radiat. Res.* 164, 163-172, 2005.

There has been considerable interest in the biological effects of exposure to radiofrequency electromagnetic radiation, given the explosive growth of cellular telephone use, with the possible induction of malignancy being a significant concern. Thus the determination of whether nonthermal effects of radiofrequency electromagnetic radiation contribute to the process leading to malignancy is an important task. One proposed pathway to malignancy involves the induction of the stress response by exposures to cell phone frequency microwaves. The first step in the induction of the stress response is the activation of the DNA-binding activity of the specific transcription factor involved in this response, the heat-shock factor (HSF). The DNA-binding activity of HSF in hamster, mouse and human cells was determined after acute and continuous exposures to frequency domain multiple access (FDMA)- or code domain multiple access (CDMA)-modulated microwaves at low (0.6 W/kg) or high (approximately 5 W/kg) SARs at frequencies used for mobile communication. The DNA-binding activity of HSF was monitored using a gel shift assay; the calibration of this assay indicated that an increase of approximately 10% in the activation of the DNA-binding activity of HSF after a 1 degrees C increase in temperature could be detected. We failed to detect any increase in the DNA-binding ability of HSF in cultured mammalian cells as a consequence of any exposure tested, within the sensitivity of our assay. Our results do not support the notion that the stress response is activated as a consequence of exposure to microwaves of frequencies associated with mobile communication devices.

Lebedeva NN, Sulimov AV, Sulimova OP, Kotrovskaya TI, Gailus T, Cellular phone electromagnetic field effects on bioelectric activity of human brain. *Crit Rev Biomed Eng* 28(1-2):323-337, 2000.

24 volunteers participated in the experiments. The investigation of EEG reactions to cellular phone (EMF frequency 902.4 MHz and intensity 0.06 mW/cm²) was conducted. Two experiments were performed with each subject--cellular phone exposure and Placebo. Duration of the experiment was 60 min: 15 min--background; 15 min--EMF exposure or Placebo; 30 min--afterexposure. EEG was recorded in 16 standard leads with "eyes open" and "eyes closed". Special software with non-linear dynamics was developed for EEG analyses. One parameter, multichannel (global) correlation dimension, was calculated. The changes of these parameters can be evidence of brain functional state changes. As a result of EEG record processing, a significant increase of global correlation dimension during the exposure and afterexposure period was discovered, more pronounced in the case of "eyes closed". That can be viewed as the manifestation of cortex activation under phone EMF exposure.

Lebedeva NN, Sulimov AV, Sulimova OP, Korotkovskaya TI, Gailus T, Investigation of brain potentials in sleeping humans exposed to the electromagnetic field of mobile phones. *Crit Rev Biomed Eng* 29(1):125-133, 2001.

An investigation was made of 8-hour EEG tracings of sleeping humans exposed to the electromagnetic field of a GSM-standard mobile phone. To analyze the EEG-patterns, manual scoring, nonlinear dynamics, and spectral analysis were employed. It was found that, when human beings were exposed to the electromagnetic field of a cellular phone, their cerebral cortex biopotentials revealed an increase in the alpha-range power density as compared to the placebo experiment. It was also found that the dimension of EEG correlation dynamics and the relation of sleep stages changed under the influence of the electromagnetic field of a mobile phone.

Lee JJ, Kwak HJ, Lee YM, Lee JW, Park MJ, Ko YG, Choi HD, Kim N, Pack JK, Hong SI, Lee JS. Acute radio frequency irradiation does not affect cell cycle, cellular migration, and invasion. *Bioelectromagnetics*. 29(8):615-625, 2008.

Although in vitro studies have been previously conducted to determine the biological effects of radio frequency (RF) radiation, it has not yet been determined whether or not RF radiation poses a potential hazard. This study was conducted to determine whether RF radiation exposure exerts detectable effects on cell cycle distribution, cellular invasion, and migration. NIH3T3 mouse fibroblasts were exposed to 849 MHz of RF radiation at average SAR values of 2 or 10 W/kg for either 1 h, or for 1 h per day for 3 days. During the exposure period, the temperature in the exposure chamber was maintained isothermally by circulating water throughout the cavity. Cell cycle distribution was analyzed at 24 and 48 h after exposure, by flow cytometry. We detected no statistically significant differences between the sham-exposed and RF radiation-exposed cells. Cellular invasion and migration were assessed by in vitro Matrigel invasion and Transwell migration assays. The RF radiation-exposed groups evidenced no significant changes in motility and invasiveness.

compared to the sham-exposed group. However, the ionizing radiation-exposed cells, used as a positive control group, manifested dramatic alterations in their cell cycle distribution, cellular invasiveness, and migration characteristics. Our results show that 849 MHz RF radiation exposure exerts no detectable effects on cell cycle distribution, cellular migration, or invasion at average SAR values of 2 or 10 W/kg.

Lee JS, Huang TQ, Lee JJ, Pack JK, Jang JJ, Seo JS. Subchronic exposure of hsp70.1-deficient mice to radiofrequency radiation. Int J Radiat Biol. 81(10):781-792, 2005.

Purpose: Heat shock protein 70 (HSP70) is one of the most inducible proteins to play a cytoprotective role under stressful conditions. Previously we generated hsp70.1-deficient mice to elucidate the in vivo function of HSP70 in detail. The renal tissues and embryonic fibroblasts of these mice were shown to be more vulnerable to hyperosmotic stress. Since RF (radiofrequency) energy has been suggested to be an environmental stressor, we carried out a study to determine whether sub-chronic RF exposure can cause constitutive induction of a stress response at a cellular and/or molecular level in hsp70.1-deficient mice due to repeated stimulation. **Materials and methods:** Eight-week-old hsp70.1-deficient mice were exposed twice daily for 45 min, with a 15 min interval, 5 days a week for 10 weeks. Whole-body average specific absorption rate was 0.4 W/Kg for fields of both 849 MHz and 1763 MHz. Major tissues were histopathologically analysed, and immunocytochemically evaluated for cell proliferative activity. Apoptosis was investigated by TdT-mediated dUTP nick-end labeling (TUNEL) assay. To determine whether RF radiation elicits a stress response, the expression level of heat shock proteins (HSP) and phosphorylation of the stress-activated kinases were also observed by western blots. **Results:** No difference was observed in the histopathological analysis between sham- and RF-exposed mice. There was no evidence of increased proliferative and apoptotic activities. The levels of HSP90, HSP70, and HSP25 showed no obvious changes. RF exposure did not affect the phosphorylation status of the major stress-activated kinase (MAPK); extracellular signal-regulated kinase 1/2 (ERK1/2), C-Jun N-terminal kinase 1/2 (JNK1/2) or p38 MAPK. **Conclusion:** The hsp70.1-deficient mice did not show any significant changes in terms of cell proliferation, apoptosis, or stress response due to exposure of 849 or 1,763 MHz RF fields.

Lee JS, Huang TQ, Kim TH, Kim JY, Kim HJ, Pack JK, Seo JS. Radiofrequency radiation does not induce stress response in human T-lymphocytes and rat primary astrocytes. Bioelectromagnetics. 27(7):578-588, 2006.

Heat shock proteins (HSPs) are rapidly induced by a variety of stressors, including heat shock, ethanol, heavy metals, UV, and gamma-radiation. Mitogen-activated protein kinases (MAPKs) are also involved in the stress transduction pathways in all eukaryotes. In this study, we attempted to determine whether radiofrequency (RF) radiation is able to induce a non-thermal stress response. Human T-lymphocyte Jurkat cells and rat primary astrocytes were exposed to 1763 MHz of RF radiation at an average specific absorption rate (SAR) of either 2 W/kg or 20 W/kg, for 30 min or 1 h. Temperature was completely controlled at 37 +/- 0.2 degrees C throughout the exposure period. The sham exposures were performed under exactly identical experimental conditions without exposure to RF radiation. We assessed alterations in the expression of HSPs and the activation of MAPKs in the RF-exposed cells. No detectable difference was observed in the expression levels of HSP90, HSP70, and HSP27. The phosphorylation status of MAPKs, extracellular signal-regulated kinases (ERK1/2), c-Jun N-terminal protein kinases (JNK1/2), or p38, did not change significantly. In order to determine whether RF radiation can promote the effects of 12-O-tetradecanoylphorbol 13-acetate (TPA) on stress response, cells were exposed to RF radiation coupled with TPA treatment. When TPA alone was applied, the MAPKs were found to be phosphorylated in a dose-dependent manner. However, RF radiation did not result in any enhancement of TPA-induced MAPK phosphorylation. Neither TPA nor RF radiation exerted any detectable effect on the induction of HSPs. These results indicate that 1763 MHz RF radiation alone did not elicit any stress response, nor did it have any effect on TPA-induced MAPK phosphorylation, under our experimental conditions.

Lee KS, Choi JS, Hong SY, Son TH, Yu K. Mobile phone electromagnetic radiation activates MAPK signaling and regulates viability in Drosophila. Bioelectromagnetics. 2008 Feb 19 [Epub ahead of print]

Mobile phones are widely used in the modern world. However, biological effects of electromagnetic radiation produced by mobile phones are largely unknown. In this report, we show biological effects of the mobile phone 835 MHz

electromagnetic field (EMF) in the *Drosophila* model system. When flies were exposed to the specific absorption rate (SAR) 1.6 W/kg, which is the proposed exposure limit by the American National Standards Institute (ANSI), more than 90% of the flies were viable even after the 30 h exposure. However, in the SAR 4.0 W/kg strong EMF exposure, viability dropped from the 12 h exposure. These EMF exposures triggered stress response and increased the production of reactive oxygen species. The EMF exposures also activated extracellular signal regulated kinase (ERK) and c-Jun N-terminal kinase (JNK) signaling, but not p38 kinase signaling. Interestingly, SAR 1.6 W/kg activated mainly ERK signaling and expression of an anti-apoptotic gene, whereas SAR 4.0 W/kg strongly activated JNK signaling and expression of apoptotic genes. In addition, SAR 4.0 W/kg amplified the number of apoptotic cells in the fly brain. These findings demonstrate that the exposure limit on electromagnetic radiation proposed by ANSI triggered ERK-survival signaling but the strong electromagnetic radiation activated JNK-apoptotic signaling in *Drosophila*.

Lee TMC, Ho SMY, Tsang LYH, Yang SYC, Li LSW, Chan CCH, Effect on human attention of exposure to the electromagnetic field emitted by mobile phones. *NeuroReport* 12:729-731, 2001.

This study examined the effect of exposure to the electromagnetic field emitted by mobile phones on human attention. Three measures of attention were administered to 72 teenagers, 37 of whom were mobile phone users. The results showed that the mobile phone users performed better on one of the three measures of attention than did the non-mobile phone users. The results suggest that exposure to the electromagnetic field emitted by mobile phones may have a mild facilitating effect on attention functions, which is consistent with previous observations that exposure to the electromagnetic field has a facilitating effect on cognitive processing. The possibility that mobile phone users may be naturally better at multiple tasking tasks was discussed.

Lee TM, Lam PK, Yee LT, Chan CC. The effect of the duration of exposure to the electromagnetic field emitted by mobile phones on human attention. *Neuroreport*. 14(10):1361-1364, 2003.

Previous findings suggested the facilitating effect of the electromagnetic field emitted by mobile phones on human attention. This study aimed to examine the relationship between the facilitating effect and the duration of exposure to the electromagnetic field emitted by mobile phones on human attention. Seventy-eight university students were randomly assigned to either an experimental or a control group. Their performance in the administered attention tasks was compared. Participants in the experimental group performed better on one of the two measures of attention only after they had been exposed to the electromagnetic field emitted by the mobile phone for some time. The results seem to suggest that attention functions may be differentially enhanced after exposing to the electromagnetic field emitted by mobile phones. Furthermore, this transient facilitation effect might be dose dependent.

Lerchl A, Krüger H, Niehaus M, Streckert JR, Bitz AK, Volkert Hansen V Effects of mobile phone electromagnetic fields at nonthermal SAR values on melatonin and body weight of Djungarian hamsters (*Phodopus sungorus*) *J Pineal Res* 44(3):267-272, 2008.

Abstract: In three experiments, adult male Djungarian hamsters (*Phodopus sungorus*) were exposed 24 hr/day for 60 days to radio frequency electromagnetic fields (RF-EMF) at 383, 900, and 1800 MHz, modulated according to the TETRA (383 MHz) and GSM standards (900 and 1800 MHz), respectively. A radial waveguide system ensured a well defined and uniform exposure at whole-body averaged specific absorption rates of 80 mW/kg, which is equal to the upper limit of whole-body exposure of the general population in Germany and other countries. For each experiment, using two identical waveguides, hamsters were exposed (n = 120) and sham-exposed (n = 120) in a blind fashion. In all experiments, pineal and serum melatonin levels as well as the weights of testes, brain, kidneys, and liver were not affected. At 383 MHz, exposure resulted in a significant transient increase in body weight up to 4%, while at 900 MHz this body weight increase was more pronounced (up to 6%) and not transient. At 1800 MHz, no effect on body weight was seen. The results corroborate earlier findings which have shown no effects of RF-EMF on melatonin levels in vivo and in vitro. The data are in accordance with the hypothesis that absorbed RF energy may result in metabolic changes which eventually cause body weight increases in exposed animals. The data support the notion that metabolic effects of RF-EMFs need to be investigated in more detail in future studies.

Leszczynski D, Joenväärä S, Reivinen J, Kuokka R, Non-thermal activation of the hsp27/p38MAPK stress pathway by mobile phone radiation in human endothelial cells: Molecular mechanism for cancer- and blood-brain barrier-related effects. *Differentiation* 70:120 – 129, 2002.

We have examined whether non-thermal exposures of cultures of the human endothelial cell line EA.hy926 to 900 MHz GSM mobile phone microwave radiation could activate stress response. Results obtained demonstrate that 1-hour non-thermal exposure of EA.hy926 cells changes the phosphorylation status of numerous, yet largely unidentified, proteins. One of the affected proteins was identified as heat shock protein-27 (hsp27). Mobile phone exposure caused a transient increase in phosphorylation of hsp27, an effect which was prevented by SB203580, a specific inhibitor of p38 mitogen-activated protein kinase (p38MAPK). Also, mobile phone exposure caused transient changes in the protein expression levels of hsp27 and p38MAPK. All these changes were non-thermal effects because, as determined using temperature probes, irradiation did not alter the temperature of cell cultures, which remained throughout the irradiation period at $37 \pm 0.3^\circ\text{C}$. Changes in the overall pattern of protein phosphorylation suggest that mobile phone radiation activates a variety of cellular signal transduction pathways, among them the hsp27/p38MAPK stress response pathway. Based on the known functions of hsp27, we put forward the hypothesis that mobile phone radiation-induced activation of hsp27 may (i) facilitate the development of brain cancer by inhibiting the cytochrome c/caspase-3 apoptotic pathway and (ii) cause an increase in blood-brain barrier permeability through stabilization of endothelial cell stress fibers. We postulate that these events, when occurring repeatedly over a long period of time, might become a health hazard because of the possible accumulation of brain tissue damage. Furthermore, our hypothesis suggests that other brain damaging factors may co-participate in mobile phone radiation-induced effects.

Li, JR, Chou, CK, McDougall, JA, Dasgupta, G, Wu, HH, Ren, RL, Lee, A, Han, J, Momand J TP53 tumor suppressor protein in normal human fibroblasts does not respond to 837 MHz microwave exposure. *Radiat Res* 151(6):710-716, 1999.

The TP53 tumor suppressor protein (formerly known as p53) responds to a wide variety of environmental insults. To evaluate the safety of cellular telephones, TP53 responses in human fibroblast cells were studied after exposure to 837 MHz microwaves. Cells were exposed in a temperature-controlled transverse electromagnetic (TEM) chamber to a specific absorption rate (SAR) of 0.9 or 9.0 W/kg at 837 MHz continuous-wave (CW) microwave irradiation for 2 h. The TP53 protein levels were measured by Western blot at 2, 8, 24 and 48 h after treatment. The TP53 protein levels in microwave-treated cells, sham-treated cells, and untreated cells remained unchanged relative to each other at all times tested (Fisher test and Student-Newman-Keuls test, $P > 0.05$). No morphological alterations were observed in microwave-treated cells compared to sham-treated cells. We conclude that TP53 protein expression levels in cultured human fibroblast cells do not change significantly during a 48-h period after exposure to 837 MHz continuous microwaves for 2 h at SAR levels of 0.9 or 9.0 W/kg.

Li L, Bisht KS, LaGroye I, Zhang P, Straube WL, Moros EG, Roti Roti JL. Measurement of DNA damage in mammalian cells exposed in vitro to radiofrequency fields at sars of 3-5 w/kg. *Radiat Res* 156:328-332, 2001.

In the present study, we determined whether exposure of mammalian cells to 3.2-5.1 W/kg specific absorption rate (SAR) radiofrequency fields could induce DNA damage in murine C3H 10T(1/2) fibroblasts. Cell cultures were exposed to 847.74 MHz code-division multiple access (CDMA) and 835.62 frequency-division multiple access (FDMA) modulated radiations in radial transmission line (RTL) irradiators in which the temperature was regulated to 37.0 ± 0.3 degrees C. Using the alkaline comet assay to measure DNA damage, we found no statistically significant differences in either comet moment or comet length between sham-exposed cells and those exposed for 2, 4 or 24 h to CDMA or FDMA radiations in either exponentially growing or plateau-phase cells. Further, a 4-h incubation after the 2-h exposure resulted in no significant changes in comet moment or comet length. Our results show that exposure of cultured C3H 10T(1/2) cells at 37 degrees C CDMA or FDMA at SAR values of up to 5.1 W/kg did not induce measurable DNA damage.

Lim HB, Cook GG, Barker AT, Coulton LA. Effect of 900 MHz Electromagnetic Fields on Nonthermal Induction of Heat-Shock Proteins in Human Leukocytes. *Radiat Res.* 163(1):45-52, 2005.

Despite many studies, the evidence as to whether radiofrequency fields are detrimental to health remains controversial, and the debate continues. Cells respond to some abnormal physiological conditions by producing cytoprotective heat-shock (or stress) proteins. The aim of this study was to determine whether exposure to mobile phone-type radiation causes a nonthermal stress response in human leukocytes. Human peripheral blood was sham-exposed or exposed to 900 MHz fields (continuous-wave or GSM-modulated signal) at three average specific absorption rates (0.4, 2.0 and 3.6 W/kg) for different durations (20 min, 1 h and 4 h) in a calibrated TEM cell placed in an incubator to give well-controlled atmospheric conditions at 37 degrees C and 95% air/5% CO₂. Positive (heat-stressed at 42 degrees C) and negative (kept at 37 degrees C) control groups were incubated simultaneously in the same incubator. Heat caused an increase in the number of cells expressing stress proteins (HSP70, HSP27), measured using flow cytometry, and this increase was dependent on time. However, no statistically significant difference was detected in the number of cells expressing stress proteins after RF-field exposure. These results suggest that mobile phone-type radiation is not a stressor of normal human lymphocytes and monocytes, in contrast to mild heating.

Linnet MS, Taggart T, Severson RK, Cerhan JR, Cozen W, Hartge P, Colt J. Cellular telephones and non-Hodgkin lymphoma. *Int J Cancer*. 119(10):2382-2388, 2006.

Dramatic increase in hand-held cellular telephone use since the 1980s and excess risk of lymphoproliferative malignancies associated with radio-frequency radiation (RFR) exposures in epidemiological and experimental studies motivated assessment of cellular telephones within a comprehensive US case-control investigation of non-Hodgkin lymphoma (NHL). A questionnaire ascertained cellular telephone use in 551 NHL cases and 462 frequency-matched population controls. Compared to persons who had never used cellular telephones, risks were not increased among individuals whose lifetime use was fewer than 10 (odds ratio (OR) = 0.9, 95% confidence intervals (CI): 0.6, 1.3), 10-100 (OR = 1.0, 95 % CI: 0.7, 1.5) or more than 100 times (e.g., regular users, OR = 0.9, 95% CI: 0.6, 1.4). Among regular users compared to those who had never used hand-held cellular telephones, risks of NHL were not significantly associated with minutes per week, duration, cumulative lifetime or year of first use, although NHL was non-significantly higher in men who used cellular telephones for more than 8 years. Little evidence linked use of cellular telephones with total, diffuse large B-cell lymphoma or follicular NHL. These findings must be interpreted in the context of less than 5% of the population reporting duration of use of 6 or more years or lifetime cumulative use of 200 or more hours.

Linz, KW, von Westphalen, C, Streckert, J, Hansen, V, Meyer, R, Membrane potential and currents of isolated heart muscle cells exposed to pulsed radio frequency fields. *Bioelectromagnetics* 20(8):497-511, 1999.

The influence of radio frequency (RF) fields of 180, 900, and 1800 MHz on the membrane potential, action potential, L-type Ca(2+) current and potassium currents of isolated ventricular myocytes was tested. The study is based on 90 guinea-pig myocytes and 20 rat myocytes. The fields were applied in rectangular waveguides (1800 MHz at 80, 480, 600, 720, or 880 mW/kg and 900 MHz, 250 mW/kg) or in a TEM-cell (180 MHz, 80 mW/kg and 900 MHz, 15 mW/kg). Fields of 1800 and 900 MHz were pulsed according to the GSM-standard of cellular phones. The specific absorption rates were determined from computer simulations of the electromagnetic fields inside the exposure devices by considering the structure of the physiological test arrangement. The electrical membrane parameters were measured by whole cell patch-clamp. None of the tested electrophysiological parameters was changed significantly by exposure to RF fields. Another physical stimulus, lowering the temperature from 36 degrees C to 24 degrees C, decreased the current amplitude almost 50% and shifted the voltage dependence of the steady state activation parameter d(infinity) and inactivation parameter f(infinity) of L-type Ca(2+) current by about 5 mV. However, at this lower temperature RF effects (900 MHz, 250 mW/kg; 1800 MHz, 480 mW/kg) on L-type Ca(2+) current were also not detected.

Litovitz TA, Krause D, Penafiel M, Elson EC, Mullins JM, The role of coherence time in the effect of microwaves on ornithine decarboxylase activity. *Bioelectromagnetics* 14(5):395-403, 1993.

Previously, we demonstrated the requirements for a minimum coherence time of an applied, small amplitude (10 microT) ELF magnetic field if the field were to produce an enhancement of ornithine decarboxylase activity in L929 fibroblasts. Further investigation has revealed a remarkably similar coherence time phenomenon for enhancement of ornithine decarboxylase activity by amplitude-modulated 915 MHz microwaves of large amplitude (SAR 2.5 W/kg). Microwave

fields modulated at 55, 60, or 65 Hz approximately doubled ornithine decarboxylase activity after 8 h. Switching modulation frequencies from 55 to 65 Hz at coherence times of 1.0 s or less abolished enhancement, while times of 10 s or longer provided full enhancement. Our results show that the microwave coherence effects are remarkably similar to those observed with ELF fields.

Litovitz, TA, Penafiel, LM, Farrel, JM, Krause, D, Meister, R, Mullins, JM Bioeffects induced by exposure to microwaves are mitigated by superposition of ELF noise. *Bioelectromagnetics* 18(6):422-430, 1997.

We have previously demonstrated that microwave fields, amplitude modulated (AM) by an extremely low-frequency (ELF) sine wave, can induce a nearly twofold enhancement in the activity of ornithine decarboxylase (ODC) in L929 cells at SAR levels of the order of 2.5 W/kg. Similar, although less pronounced, effects were also observed from exposure to a typical digital cellular phone test signal of the same power level, burst modulated at 50 Hz. We have also shown that ODC enhancement in L929 cells produced by exposure to ELF fields can be inhibited by superposition of ELF noise. In the present study, we explore the possibility that similar inhibition techniques can be used to suppress the microwave response. We concurrently exposed L929 cells to 60 Hz AM microwave fields or a 50 Hz burst-modulated DAMPS (Digital Advanced Mobile Phone System) digital cellular phone field at levels known to produce ODC enhancement, together with band-limited 30-100 Hz ELF noise with root mean square amplitude of up to 10 microT. All exposures were carried out for 8 h, which was previously found to yield the peak microwave response. In both cases, the ODC enhancement was found to decrease exponentially as a function of the noise root mean square amplitude. With 60 Hz AM microwaves, complete inhibition was obtained with noise levels at or above 2 microT. With the DAMPS digital cellular phone signal, complete inhibition occurred with noise levels at or above 5 microT. These results suggest a possible practical means to inhibit biological effects from exposure to both ELF and microwave fields.

Lixia S, Yao K, Kaijun W, Deqiang L, Huajun H, Xiangwei G, Baohong W, Wei Z, Jianling L, Wei W. Effects of 1.8GHz radiofrequency field on DNA damage and expression of heat shock protein 70 in human lens epithelial cells. *Mutat Res*. 2006 Sep 29; [Epub ahead of print]

To investigate the DNA damage, expression of heat shock protein 70 (Hsp70) and cell proliferation of human lens epithelial cells (hLEC) after exposure to the 1.8GHz radiofrequency field (RF) of a global system for mobile communications (GSM). An Xc-1800 RF exposure system was used to employ a GSM signal at 1.8GHz (217Hz amplitude-modulated) with the output power in the specific absorption rate (SAR) of 1, 2 and 3W/kg. After 2h exposure to RF, the DNA damage of hLEC was accessed by comet assay at five different incubation times: 0, 30, 60, 120 and 240min, respectively. Western blot and RT-PCR were used to determine the expression of Hsp70 in hLECs after RF exposure. The proliferation rate of cells was evaluated by bromodeoxyuridine incorporation on days 0, 1 and 4 after exposure. The results show that the difference of DNA-breaks between the exposed and sham-exposed (control) groups induced by 1 and 2W/kg irradiation were not significant at any incubation time point ($P>0.05$). The DNA damage caused by 3W/kg irradiation was significantly increased at the times of 0 and 30min after exposure ($P<0.05$), a phenomenon that could not be seen at the time points of 60, 120 or 240min ($P>0.05$). Detectable mRNA as well as protein expression of Hsp70 was found in all groups. Exposure at SARs of 2 and 3W/kg for 2h exhibited significantly increased Hsp70 protein expression ($P<0.05$), while no change in Hsp70 mRNA expression could be found in any of the groups ($P>0.05$). No difference of the cell proliferation rate between the sham-exposed and exposed cells was found at any exposure dose tested ($P>0.05$). The results indicate that exposure to non-thermal dosages of RF for wireless communications can induce no or repairable DNA damage and the increased Hsp70 protein expression in hLECs occurred without change in the cell proliferation rate. The non-thermal stress response of Hsp70 protein increase to RF exposure might be involved in protecting hLEC from DNA damage and maintaining the cellular capacity for proliferation.

Lonn S, Ahlbom A, Hall P, Feychting M. Mobile Phone Use and the Risk of Acoustic Neuroma. *Epidemiology*. 15(6):653-659, 2004.

BACKGROUND:: Radiofrequency exposure from mobile phones is concentrated to the tissue closest to the handset, which includes the auditory nerve. If this type of exposure increases tumor risk, acoustic neuroma would be a potential concern. **METHODS::** In this population-based case-control study we identified all cases age 20 to 69 years diagnosed with acoustic neuroma during 1999 to 2002 in certain parts of Sweden. Controls were randomly selected from the study

base, stratified on age, sex, and residential area. Detailed information about mobile phone use and other environmental exposures was collected from 148 (93%) cases and 604 (72%) controls. RESULTS:: The overall odds ratio for acoustic neuroma associated with regular mobile phone use was 1.0 (95% confidence interval = 0.6-1.5). Ten years after the start of mobile phone use the estimates relative risk increased to 1.9 (0.9-4.1); when restricting to tumors on the same side of the head as the phone was normally used, the relative risk was 3.9 (1.6-9.5). CONCLUSIONS:: Our findings do not indicate an increased risk of acoustic neuroma related to short-term mobile phone use after a short latency period. However, our data suggest an increased risk of acoustic neuroma associated with mobile phone use of at least 10 years' duration.

Lonn S, Ahlbom A, Hall P, Feychting M. Long-term mobile phone use and brain tumor risk. *Am J Epidemiol.* 161(6):526-535, 2005.

Handheld mobile phones were introduced in Sweden during the late 1980s. The purpose of this population-based, case-control study was to test the hypothesis that long-term mobile phone use increases the risk of brain tumors. The authors identified all cases aged 20-69 years who were diagnosed with glioma or meningioma during 2000-2002 in certain parts of Sweden. Randomly selected controls were stratified on age, gender, and residential area. Detailed information about mobile phone use was collected from 371 (74%) glioma and 273 (85%) meningioma cases and 674 (71%) controls. For regular mobile phone use, the odds ratio was 0.8 (95% confidence interval: 0.6, 1.0) for glioma and 0.7 (95% confidence interval: 0.5, 0.9) for meningioma. Similar results were found for more than 10 years' duration of mobile phone use. No risk increase was found for ipsilateral phone use for tumors located in the temporal and parietal lobes. Furthermore, the odds ratio did not increase, regardless of tumor histology, type of phone, and amount of use. This study includes a large number of long-term mobile phone users, and the authors conclude that the data do not support the hypothesis that mobile phone use is related to an increased risk of glioma or meningioma.

[Lonn S, Ahlbom A, Christensen HC, Johansen C, Schuz J, Edstrom S, Henriksson G, Lundgren J, Wennerberg J, Feychting M. Mobile Phone Use and Risk of Parotid Gland Tumor. *Am J Epidemiol.* 2006 Jul 3; \[Epub ahead of print\]](#)

Handheld mobile phones were introduced in Denmark and Sweden during the late 1980s. This makes the Danish and Swedish populations suitable for a study aimed at testing the hypothesis that long-term mobile phone use increases the risk of parotid gland tumors. In this population-based case-control study, the authors identified all cases aged 20-69 years diagnosed with parotid gland tumor during 2000-2002 in Denmark and certain parts of Sweden. Controls were randomly selected from the study population base. Detailed information about mobile phone use was collected from 60 cases of malignant parotid gland tumors (85% response rate), 112 benign pleomorphic adenomas (88% response rate), and 681 controls (70% response rate). For regular mobile phone use, regardless of duration, the risk estimates for malignant and benign tumors were 0.7 (95% confidence interval: 0.4, 1.3) and 0.9 (95% confidence interval: 0.5, 1.5), respectively. Similar results were found for more than 10 years' duration of mobile phone use. The risk estimate did not increase, regardless of type of phone and amount of use. The authors conclude that the data do not support the hypothesis that mobile phone use is related to an increased risk of parotid gland tumors.

[Lopez-Martin E, Relova-Quinteiro JL, Gallego-Gomez R, Peleteiro-Fernandez M, Jorge-Barreiro FJ, Ares-Pena FJ. GSM radiation triggers seizures and increases cerebral c-Fos positivity in rats pretreated with subconvulsive doses of picrotoxin. *Neurosci Lett.* 2006 Jan 27; \[Epub ahead of print\]](#)

This study investigated the effects of mobile-phone-type radiation on the cerebral activity of seizure-prone animals. When rats transformed into an experimental model of seizure-proneness by acute subconvulsive doses of picrotoxin were exposed to 2h GSM-modulated 900MHz radiation at an intensity similar to that emitted by mobile phones, they suffered seizures and the levels of the neuronal activity marker c-Fos in neocortex, paleocortex, hippocampus and thalamus increased markedly. Non-irradiated picrotoxin-treated rats did not suffer seizures, and their cerebral c-Fos counts were significantly lower. Radiation caused no such differences in rats that had not been pretreated with picrotoxin. We conclude that GSM-type radiation can induce seizures in rats following their facilitation by subconvulsive doses of picrotoxin, and that research should be pursued into the possibility that this kind of radiation may similarly affect brain function in human subjects with epileptic disorders.

López-Martín E, Bregains J, Relova-Quinteiro JL, Cadarso-Suárez C, Jorge-Barreiro FJ, Ares-Pena FJ. The action of pulse-modulated GSM radiation increases regional changes in brain activity and c-Fos expression in cortical and subcortical areas in a rat model of picrotoxin-induced seizure proneness. J Neurosci Res. 2008 Dec 29. [Epub ahead of print]

The action of the pulse-modulated GSM radiofrequency of mobile phones has been suggested as a physical phenomenon that might have biological effects on the mammalian central nervous system. In the present study, GSM-exposed picrotoxin-pretreated rats showed differences in clinical and EEG signs, and in c-Fos expression in the brain, with respect to picrotoxin-treated rats exposed to an equivalent dose of unmodulated radiation. Neither radiation treatment caused tissue heating, so thermal effects can be ruled out. The most marked effects of GSM radiation on c-Fos expression in picrotoxin-treated rats were observed in limbic structures, olfactory cortex areas and subcortical areas, the dentate gyrus, and the central lateral nucleus of the thalamic intralaminar nucleus group. Nonpicrotoxin-treated animals exposed to unmodulated radiation showed the highest levels of neuronal c-Fos expression in cortical areas. These results suggest a specific effect of the pulse modulation of GSM radiation on brain activity of a picrotoxin-induced seizure-proneness rat model and indicate that this mobile-phone-type radiation might induce regional changes in previous preexcitability conditions of neuronal activation.

López-Martín E, Bregains J, Relova-Quinteiro JL, Cadarso-Suárez C, Jorge-Barreiro FJ, Ares-Pena FJ. The action of pulse-modulated GSM radiation increases regional changes in brain activity and c-Fos expression in cortical and subcortical areas in a rat model of picrotoxin-induced seizure proneness. *J Neurosci Res.* 87(6):1484-1499, 2009.

The action of the pulse-modulated GSM radiofrequency of mobile phones has been suggested as a physical phenomenon that might have biological effects on the mammalian central nervous system. In the present study, GSM-exposed picrotoxin-pretreated rats showed differences in clinical and EEG signs, and in c-Fos expression in the brain, with respect to picrotoxin-treated rats exposed to an equivalent dose of unmodulated radiation. Neither radiation treatment caused tissue heating, so thermal effects can be ruled out. The most marked effects of GSM radiation on c-Fos expression in picrotoxin-treated rats were observed in limbic structures, olfactory cortex areas and subcortical areas, the dentate gyrus, and the central lateral nucleus of the thalamic intralaminar nucleus group. Nonpicrotoxin-treated animals exposed to unmodulated radiation showed the highest levels of neuronal c-Fos expression in cortical areas. These results suggest a specific effect of the pulse modulation of GSM radiation on brain activity of a picrotoxin-induced seizure-proneness rat model and indicate that this mobile-phone-type radiation might induce regional changes in previous preexcitability conditions of neuronal activation.

Loscher W, Kas G, Extraordinary behavior disorders in cows in proximity to transmission stations. *Der Praktische Tierarz* 79:437-444, 1998.

(Article in German)

In addition to reduction of milk yield and increased health problems, behavioral abnormalities were observed over a period of two years in a herd of dairy cows maintained in close proximity to a TV and cell phone transmitting antenna. Evaluation of possible factors which could explain the abnormalities in the live stock did not disclose any factors other than the high-frequency electromagnetic fields. An experiment in which a cow with abnormal behavior was brought to a stable 20 km away from the antenna resulted in a complete normalization of the cow within five days, whereas symptoms returned when the cow was brought back to the stable nearby the antenna. In view of the previous described effects of electromagnetic fields, it might be possible that the observed abnormalities in cows are related to electromagnetic field exposure. (power densities measured 0.02-7 mW/m²).

Loughran SP, Wood AW, Barton JM, Croft RJ, Thompson B, Stough C. The effect of electromagnetic fields emitted by mobile phones on human sleep. *Neuroreport.* 16(17):1973-1976, 2005.

Previous research has suggested that exposure to radiofrequency electromagnetic fields increases electroencephalogram spectral power in non-rapid eye movement sleep. Other sleep parameters have also been affected following exposure. We examined whether aspects of sleep architecture show sensitivity to electromagnetic fields emitted by digital mobile phone

handsets. Fifty participants were exposed to electromagnetic fields for 30 min prior to sleep. Results showed a decrease in rapid eye movement sleep latency and increased electroencephalogram spectral power in the 11.5-12.25 Hz frequency range during the initial part of sleep following exposure. These results are evidence that mobile phone exposure prior to sleep may promote rapid eye movement sleep and modify the sleep electroencephalogram in the first non-rapid eye movement sleep period.

Luukkonen J, Hakulinen P, Mäki-Paakkanen J, Juutilainen J, Naarala J. Enhancement of chemically induced reactive oxygen species production and DNA damage in human SH-SY5Y neuroblastoma cells by 872MHz radiofrequency radiation. *Mutat Res.* 662(1-2):54-58, 2009.

The objective of the study was to investigate effects of 872MHz radiofrequency (RF) radiation on intracellular reactive oxygen species (ROS) production and DNA damage at a relatively high SAR value (5W/kg). The experiments also involved combined exposure to RF radiation and menadione, a chemical inducing intracellular ROS production and DNA damage. The production of ROS was measured using the fluorescent probe dichlorofluorescein and DNA damage was evaluated by the Comet assay. Human SH-SY5Y neuroblastoma cells were exposed to RF radiation for 1h with or without menadione. Control cultures were sham exposed. Both continuous waves (CW) and a pulsed signal similar to that used in global system for mobile communications (GSM) mobile phones were used. Exposure to the CW RF radiation increased DNA breakage ($p<0.01$) in comparison to the cells exposed only to menadione. Comparison of the same groups also showed that ROS level was higher in cells exposed to CW RF radiation at 30 and 60min after the end of exposure ($p<0.05$ and $p<0.01$, respectively). No effects of the GSM signal were seen on either ROS production or DNA damage. The results of the present study suggest that 872MHz CW RF radiation at 5W/kg might enhance chemically induced ROS production and thus cause secondary DNA damage. However, there is no known mechanism that would explain such effects from CW RF radiation but not from GSM modulated RF radiation at identical SAR.

Maby E, Le Bouquin Jeannes R, Liegeois-Chauvel C, Gourevitch B, Faucon G. Analysis of auditory evoked potential parameters in the presence of radiofrequency fields using a support vector machines method. *Med Biol Eng Comput.* 42(4):562-568, 2004.

The paper presents a study of global system for mobile (GSM) phone radiofrequency effects on human cerebral activity. The work was based on the study of auditory evoked potentials (AEPs) recorded from healthy humans and epileptic patients. The protocol allowed the comparison of AEPs recorded with or without exposure to electrical fields. Ten variables measured from AEPs were employed in the design of a supervised support vector machines classifier. The classification performance measured the classifier's ability to discriminate features performed with or without radiofrequency exposure. Most significant features were chosen by a backward sequential selection that ranked the variables according to their pertinence for the discrimination. Finally, the most discriminating features were analysed statistically by a Wilcoxon signed rank test. For both populations, the N100 amplitudes were reduced under the influence of GSM radiofrequency (mean attenuation of -0.36 microV for healthy subjects and -0.60 microV for epileptic patients). Healthy subjects showed a N100 latency decrease (-5.23 ms in mean), which could be consistent with mild, localised heating. The auditory cortical activity in humans was modified by GSM phone radiofrequencies, but an effect on brain functionality has not been proven.

Maby E, Jeannes RL, Faucon G, Liegeois-Chauvel C, De Seze R. Effects of GSM signals on auditory evoked responses. *Bioelectromagnetics.* 2005 May 10; [Epub ahead of print]

The article presents a study of the influence of radio frequency (RF) fields emitted by mobile phones on human cerebral activity. Our work was based on the study of Auditory Evoked Potentials (AEPs) recorded on the scalp of healthy humans and epileptic patients. The protocol allowed us to compare AEPs recorded with or without exposure to RFs. To get a reference, a control session was also introduced. In this study, the correlation coefficients computed between AEPs, as well as the correlation coefficients between spectra of AEPs were investigated to detect a possible difference due to RFs. A difference in the correlation coefficients computed in control and experimental sessions was observed, but it was difficult to deduce the effect of RFs on human health.

Maby E, Jeannes Rle B, Faucon G. Scalp localization of human auditory cortical activity modified by GSM electromagnetic fields. *Int J Radiat Biol.* 82(7):465-472, 2006.

Purpose: This study attempted to determine whether there is a localized effect of GSM (Global System for Mobile communications) microwaves by studying the Auditory Evoked Potentials (AEP) recorded at the scalp of nine healthy subjects and six epileptic patients. **Materials and methods:** We determined the influence of GSM RadioFrequency (RF) on parameters characterizing the AEP in time or/and frequency domains. A parameter selection method using SVM (Support Vector Machines)-based criteria allowed us to estimate those most altered by the radiofrequencies. The topography of the parameter modifications was computed to determine the localization of the radiofrequency influence. A statistical test was conducted for selected scalp areas, in order to determine whether there were significant localized alterations due to the RF. **Results:** The epileptic patients showed a lengthening of the scalp component N100 (100 ms latency) in the frontal area contralateral to the radiation, which may be due to an afferent tract alteration. For the healthy subjects, an amplitude increase of the P200 wave (200 ms latency) was identified in the frontal area. **Conclusions:** The present study suggests that radiofrequency fields emitted by mobile phones modify the AEP. Nevertheless, no direct link between these findings and RF-induced damages in brain function was established.

Maby E, Le Bouquin Jeannes R, Faucon G. Short-term effects of GSM mobiles phones on spectral components of the human electroencephalogram. *Conf Proc IEEE Eng Med Biol Soc.* 1:3751-3754, 2006.

The aim of the study was to investigate whether the GSM (global system for mobile) signals affect the electrical activity of the human brain. Nine healthy subjects and six temporal epileptic patients were exposed to radiofrequencies emitted by a GSM mobile phone signals. Electroencephalographic (EEG) signals were recorded using surface electrodes with and without radiofrequency. In order to obtain a reference, a control session was also carried out. The spectral attributes of the EEG signals recorded by surface electrodes were analyzed. The significant decrease of spectral correlation coefficients under radiofrequency influence showed that the GSM signal altered the spectral arrangement of the EEG activity for healthy subjects as well as epileptic patients. For the healthy subjects, the EEG spectral energy decreased on the studied frequency band [0-40 Hz] and more precisely on occipital electrodes for the alpha-band. For the epileptic patients, these modifications were demonstrated by an increase of the power spectral density of the EEG signal. Nevertheless, these biological effects on the EEG are not sufficient to put forward some electrophysiological hypothesis.

Maccà I, Scapellato ML, Carrieri M, Pasqua di Bisceglie A, Saia B, Bartolucci GB. Occupational exposure to electromagnetic fields in physiotherapy departments. *Radiat Prot Dosimetry.* 128(2):180-190, 2008.

To assess occupational exposure to electromagnetic fields, 11 microwave (MW), 4 short-wave diathermy and 15 magneto therapy devices were analysed in eight physiotherapy departments. Measurements taken at consoles and environmental mapping showed values above European Directive 2004/40/EC and ACGIH exposure limits at approximately 50 cm from MW applicators (2.45 GHz) and above the Directive magnetic field limit near the diathermy unit (27.12 MHz). Levels in front of MW therapy applicators decreased rapidly with distance and reduction in power; this may not always occur in work environments where nearby metal structures (chairs, couches, etc.) may reflect or perturb electromagnetic fields. Large differences in stray field intensities were found for various MW applicators. Measurements of power density strength around MW electrodes confirmed radiation fields between 30 degrees and 150 degrees , with a peak at 90 degrees , in front of the cylindrical applicator and maximum values between 30 degrees and 150 degrees over the whole range of 180 degrees for the rectangular parabolic applicator. Our results reveal that although most areas show substantially low levels of occupational exposure to electromagnetic fields in physiotherapy units, certain cases of over-occupational exposure limits do exist.

Maes A, Collier M, Slaets D, Verschaeve L, 954 MHz microwaves enhance the mutagenic properties of mitomycin C. *Environ Mol Mutagen* 28(1):26-30, 1996.

This paper focuses on the combined effects of microwaves from mobile communication frequencies and a chemical DNA damaging agent mitomycin C (MMC). The investigation was performed in vitro by exposing whole blood samples to a 954 MHz emitting antenna from a GSM (Global System for Mobile Communication) base station, followed by lymphocyte cultivation in the presence of MMC. A highly reproducible synergistic effect was observed as based on the frequencies of sister chromatid exchanges in metaphase figures.

Maes A, Collier M, Van Gorp U, Vandoninck S, Verschaeve L, Cytogenetic effects of 935.2-MHz (GSM) microwaves alone and in combination with mitomycin C. *Mutat Res* 393(1-2):151-156, 1997.

This paper focuses on the genetic effects of microwaves from mobile communication frequencies (935.2 MHz) alone and in combination with a chemical DNA-damaging agent (mitomycin C). Three cytogenetic endpoints were investigated after in vitro exposure of human whole blood cells. These endpoints were the 'classical' chromosome aberration test, the sister chromatid exchange test and the alkaline comet assay. No direct cytogenetic effect was found. The combined exposure of the cells to the radiofrequency fields followed by their cultivation in the presence of mitomycin C revealed a very weak effect when compared to cells exposed to mitomycin C alone.

Maes A, Collier M, Verschaeve L Cytogenetic effects of 900 MHz (GSM) microwaves on human lymphocytes. *Bioelectromagnetics* 22(2):91-96, 2001

The cytogenetic effects of 900 MHz radiofrequency fields were investigated with the chromosome aberration and sister chromatid exchange frequency methods. Three different modes of exposure (continuous, pseudo-random and dummy burst) were studied for different power outputs (0, 2, 8, 15, 25, 50 W). The specific absorption rates varied between 0 and 10 W/kg. We investigated the possible effects of the 900 MHz radiation alone as well as of combined exposure to the chemical or physical mutagens mitomycin C and X-rays. Overall, no indication was found of a mutagenic, and/or co-mutagenic/synergistic effect of this kind of nonionizing radiation.

[Maes A](#), [Van Gorp U](#), [Verschaeve L](#). Cytogenetic investigation of subjects professionally exposed to radiofrequency radiation. [Mutagenesis](#). 2006 Feb 15; [Epub ahead of print]

Nowadays, virtually everybody is exposed to radiofrequency radiation (RFR) from mobile phone base station antennas or other sources. At least according to some scientists, this exposure can have detrimental health effects. We investigated cytogenetic effects in peripheral blood lymphocytes from subjects who were professionally exposed to mobile phone electromagnetic fields in an attempt to demonstrate possible RFR-induced genetic effects. These subjects can be considered well suited for this purpose as their RFR exposure is 'normal' though rather high, and definitely higher than that of the 'general population'. The alkaline comet assay, sister chromatid exchange (SCE) and chromosome aberration tests revealed no evidence of RFR-induced genetic effects. Blood cells were also exposed to the well known chemical mutagen mitomycin C in order to investigate possible combined effects of RFR and the chemical. No cooperative action was found between the electromagnetic field exposure and the mutagen using either the comet assay or SCE test.

Maier R, Greter SE, Maier N. Effects of pulsed electromagnetic fields on cognitive processes - a pilot study on pulsed field interference with cognitive regeneration. *Acta Neurol Scand.* 110(1):46-52, 2004.

BACKGROUND: Due to the ubiquitous use of cellular phones much has been speculated on secondary effects of electromagnetic irradiation emitted by those. Additionally, several studies have reported vegetative alterations as well as effects on the neuronal and molecular levels in humans. Here, using a psycho-physiological test paradigm, we examined effects of exposure to pulsed electromagnetic fields on cognitive performance. **MATERIALS AND METHODS:** In 11 volunteers, we tested cognitive processing under field exposure (GSM standard) and under field-free conditions. To examine the hypothesized effect of pulsed fields, we applied an auditory discrimination task and determined the participant's current 'Order Threshold' value. Following a first test cycle, the volunteers had to relax for 50 min while being, or not, exposed to pulsed electromagnetic fields. Subsequently, the test was repeated. Data acquired before and after the resting phase were compared from both experimental conditions. **RESULTS:** We found that nine of the 11 test participants (81.8%) showed worse results in their auditory discrimination performance upon field exposure as compared with control conditions. Group data comparison revealed a statistical significance of $P = 0.0105$. **CONCLUSION:** We could show that the participants' cognitive performance was impaired after exposure to pulsed electromagnetic fields. With regard to this finding, we recommend that the use of cellular phones should be restricted generally and in particular in respect of physical hazard of high-risk groups, e.g. elderly, children and ill people.

Markova E, Hillert L, Malmgren L, Persson BR, Belyaev IY. Microwaves from GSM Mobile Telephones Affect 53BP1 and gamma-H2AX Foci in Human Lymphocytes from Hypersensitive and Healthy Persons. *Environ Health Perspect.* 113(9):1172-1177, 2005.

The data on biologic effects of nonthermal microwaves (MWs) from mobile telephones are diverse, and these effects are presently ignored by safety standards of the International Commission for Non-Ionizing Radiation Protection (ICNIRP). In the present study, we investigated effects of MWs of Global System for Mobile Communication (GSM) at different carrier frequencies on human lymphocytes from healthy persons and from persons reporting hypersensitivity to electromagnetic fields (EMFs). We measured the changes in chromatin conformation, which are indicative of stress response and genotoxic effects, by the method of anomalous viscosity time dependence, and we analyzed tumor suppressor p53-binding protein 1 (53BP1) and phosphorylated histone H2AX (gamma-H2AX), which have been shown to colocalize in distinct foci with DNA double-strand breaks (DSBs), using immunofluorescence confocal laser microscopy. We found that MWs from GSM mobile telephones affect chromatin conformation and 53BP1/gamma-H2AX foci similar to heat shock. For the first time, we report here that effects of MWs from mobile telephones on human lymphocytes are dependent on carrier frequency. On average, the same response was observed in lymphocytes from hypersensitive and healthy subjects.

Malyapa RS, Ahern EW, Straube WL, Moros EG, Pickard WF, Roti Roti JL, Measurement of DNA damage after exposure to electromagnetic radiation in the cellular phone communication frequency band (835.62 and 847.74 MHz). *Radiat Res* 148(6):618-627, 1997.

Mouse C3H 10T1/2 fibroblasts and human glioblastoma U87MG cells were exposed to cellular phone communication frequency radiations to investigate whether such exposure produces DNA damage in in vitro cultures. Two types of frequency modulations were studied: frequency-modulated continuous-wave (FMCW), with a carrier frequency of 835.62 MHz, and code-division multiple-access (CDMA) centered on 847.74 MHz. Exponentially growing (U87MG and C3H 10T1/2 cells) and plateau-phase (C3H 10T1/2 cells) cultures were exposed to either FMCW or CDMA radiation for varying periods up to 24 h in specially designed radial transmission lines (RTLs) that provided relatively uniform exposure with a specific absorption rate (SAR) of 0.6 W/kg. Temperatures in the RTLs were monitored continuously and maintained at 37 +/- 0.3 degrees C. Sham exposure of cultures in an RTL (negative control) and 137Cs gamma-irradiated samples (positive control) were included with every experiment. The alkaline comet assay as described by Olive et al. (Exp. Cell Res. 198, 259-269, 1992) was used to measure DNA damage. No significant differences were observed between the test group exposed to FMCW or CDMA radiation and the sham-treated negative controls. Our results indicate that exposure of cultured mammalian cells to cellular phone communication frequencies under these conditions at an SAR of 0.6 W/kg does not cause DNA damage as measured by the alkaline comet assay.

Mancinelli F, Caraglia M, Abbruzzese A, d'Ambrosio G, Massa R, Bismuto E. Non-thermal effects of electromagnetic fields at mobile phone frequency on the refolding of an intracellular protein: myoglobin. *J Cell Biochem.* 93(1):188-196, 2004.

Non-thermal effects induced by exposure to microwave electromagnetic field (MW-EMF) at 1.95 MHz, a frequency used in mobile communication, have been observed on the refolding kinetics of the heme binding site in an intracellular protein: tuna myoglobin, starting from acidic conditions. We have selected myoglobin because it can be considered a good model to study protein interactions with MW-EMF for its well-known high-resolution crystallographic structure. Myoglobin solutions at pH 3.0 were subjected to 3 h exposure to microwave field (with a specific absorption rate of 51 +/- 1 mW/g); the heme site refolding has been followed by measuring the molecular absorption in the Soret spectral region and the data were fitted to a bi-exponential model. The kinetics of exposed samples appear to be slowed by MW-EMF action. Moreover, the tryptophanyl lifetime distribution of the exposed protein, as deduced by the analysis of the fluorescence emission decay from its single tryptophan, appears sharper if compared to non-exposed protein samples. This observation suggests that the presence of MW-EMF could affect the propensity of protein molecules to populate specific conformational substates among which myoglobin molecules fluctuate at acidic pH. Changes in the structural fluctuation caused by MW perturbation can affect differently the aggregation process that occurs competitively during the protein folding, so representing a potential risk for protein "misfolding." These data suggest that MW-EMF could have also biochemical and, consequently, biological effects on eukaryotic cells that are still under investigation.

Mann, K, Roschke, J, Effects of pulsed high-frequency electromagnetic fields on human sleep. *Neuropsychobiology* 33(1):41-47, 1996.

In the present study we investigated the influence of pulsed high-frequency electromagnetic fields of digital mobile radio telephones on sleep in healthy humans. Besides a hypnotic effect with shortening of sleep onset latency, a REM suppressive effect with reduction of duration and percentage of REM sleep was found. Moreover, spectral analysis revealed qualitative alterations of the EEG signal during REM sleep with an increased spectral power density. Knowing the relevance of REM sleep for adequate information processing in the brain, especially concerning mnemonic functions and learning processes, the results emphasize the necessity to carry out further investigations on the interaction of this type of electromagnetic fields and the human organism.

Mann, K, Roschke, J, Connemann, B, Beta, H, No effects of pulsed high-frequency electromagnetic fields on heart rate variability during human sleep. *Neuropsychobiology*;38(4):251-256, 1998.

The influence of pulsed high-frequency electromagnetic fields emitted by digital mobile radio telephones on heart rate during sleep in healthy humans was investigated. Beside mean RR interval and total variability of RR intervals based on calculation of the standard deviation, heart rate variability was assessed in the frequency domain by spectral power analysis providing information about the balance between the two branches of the autonomic nervous system. For most parameters, significant differences between different sleep stages were found. In particular, slow-wave sleep was characterized by a low ratio of low- and high-frequency components, indicating a predominance of the parasympathetic over the sympathetic tone. In contrast, during REM sleep the autonomic balance was shifted in favor of the sympathetic activity. For all heart rate parameters, no significant effects were detected under exposure to the field compared to placebo condition. Thus, under the given experimental conditions, autonomic control of heart rate was not affected by weak-pulsed high-frequency electromagnetic fields.

Mann, K, Wagner, P, Brunn, G, Hassan, F, Hiemke, C, Roschke, J, Effects of pulsed high-frequency electromagnetic fields on the neuroendocrine system. *Neuroendocrinology* 67(2):139-144, 1998.

The influence of pulsed high-frequency electromagnetic fields emitted from a circularly polarized antenna on the neuroendocrine system in healthy humans was investigated (900 MHz electromagnetic field, pulsed with 217 Hz, average power density 0.02 mW/cm²). Nocturnal hormone profiles of growth hormone (GH), cortisol, luteinizing hormone (LH) and melatonin were determined under polysomnographic control. An alteration in the hypothalamo-pituitary-adrenal axis activity was found with a slight, transient elevation in the cortisol serum level immediately after onset of field exposure which persisted for 1 h. For GH, LH and melatonin, no significant effects were found under exposure to the field compared to the placebo condition, regarding both total hormone production during the entire night and dynamic characteristics of the secretion pattern. Also the evaluation of the sleep EEG data revealed no significant alterations under field exposure, although there was a trend to an REM suppressive effect. The results indicate that weak high-frequency electromagnetic fields have no effects on nocturnal hormone secretion except for a slight elevation in cortisol production which is transient, pointing to an adaptation of the organism to the stimulus.

Marinelli F, La Sala D, Ciccio G, Cattini L, Trimarchi C, Putti S, Zamparelli A, Giuliani L, Tomassetti G, Cinti C. Exposure to 900 MHz electromagnetic field induces an unbalance between pro-apoptotic and pro-survival signals in T-lymphoblastoid leukemia CCRF-CEM cells. *J Cell Physiol.* 198(2):324-332, 2004.

It has been recently established that low-frequency electromagnetic field (EMFs) exposure induces biological changes and could be associated with increased incidence of cancer, while the issue remains unresolved as to whether high-frequency EMFs can have hazardous effect on health. Epidemiological studies on association between childhood cancers, particularly leukemia and brain cancer, and exposure to low- and high-frequency EMF suggested an etiological role of EMFs in inducing adverse health effects. To investigate whether exposure to high-frequency EMFs could affect in vitro cell survival, we cultured acute T-lymphoblastoid leukemia cells (CCRF-CEM) in the presence of unmodulated 900 MHz EMF, generated by a transverse electromagnetic (TEM) cell, at various exposure times. We evaluated the effects of high-frequency EMF on cell growth rate and apoptosis induction, by cell viability (MTT) test, FACS analysis and DNA ladder, and we investigated pro-apoptotic and pro-survival signaling pathways possibly involved as a function of exposure time by Western blot analysis. At short exposure times (2-12 h), unmodulated 900 MHz EMF induced DNA breaks and early activation of both p53-dependent and -independent apoptotic pathways while longer continuous exposure (24-48 h)

determined silencing of pro-apoptotic signals and activation of genes involved in both intracellular (Bcl-2) and extracellular (Ras and Akt1) pro-survival signaling. Overall our results indicate that exposure to 900 MHz continuous wave, after inducing an early self-defense response triggered by DNA damage, could confer to the survivor CCRF-CEM cells a further advantage to survive and proliferate.

Marino AA, Nilsen E, Frilot C. Nonlinear changes in brain electrical activity due to cell phone radiation. *Bioelectromagnetics* 24(5):339-346, 2003.

We studied the effect of an electromagnetic field from a cellular telephone on brain electrical activity, using a novel analytical method based on a nonlinear model. The electroencephalogram (EEG) from rabbits was embedded in phase space and local recurrence plots were calculated and quantified using recurrence quantitation analysis to permit statistical comparisons between filtered segments of exposed and control epochs from individual rabbits. When the rabbits were exposed to the radiation from a standard cellular telephone (800 MHz band, 600 mW maximum radiated power) under conditions that simulated normal human use, the EEG was significantly affected in nine of ten animals studied. The effect occurred beginning about 100 ms after initiation of application of the field and lasted approximately 300 ms. In each case, the fields increased the randomness in the EEG. A control procedure ruled out the possibility that the observations were a product of the method of analysis. No differences were found between exposed and control epochs in any animal when the experiment was repeated after the rabbits had been sacrificed, indicating that absorption of radiation by the EEG electrodes could not account for the observed effect. No effect was seen when deposition of energy in the brain was minimized by repositioning the radiating antenna from the head to the chest, showing that the type of tissue that absorbed the energy determined the observed changes in the EEG. We conclude that, in normal use, the fields from a standard cellular telephone can alter brain function as a consequence of absorption of energy by the brain.

Marino C, Cristalli G, Galloni P, Pasqualetti P, Piscitelli M, Lovisolo GA , Effects of microwaves (900 MHz) on the cochlear receptor: exposure systems and preliminary results. *Radiat Environ Biophys* 39(2):131-136, 2000.

The purpose of this paper is to present the experimental device and the work in progress performed in search for objective organic correlation of damage to hearing, examining possible acoustic otofunctional effects on the cochlear epithelium of the rat due to exposure to microwaves (900 MHz). Two experiments using male Sprague-Dawley rats were carried out with a far-field exposure in a cubic chamber. No statistically significant evidence was obtained at both specific absorption rate (SAR) values. The exposure system and the diagnostic apparatus are extremely useful to investigate a potential effect on the auditory system: however, with the parameters applied in these experiments, no evidence was observed.

Markkanen A, Penttinen P, Naarala J, Pelkonen J, Sihvonen A-P, Juutilainen J. Apoptosis induced by ultraviolet radiation is enhanced by amplitude modulated radiofrequency radiation in mutant yeast cells *Bioelectromagnetics* 25:127-133, 2004.

The aim of this study was to investigate whether radiofrequency (RF) electromagnetic field (EMF) exposure affects cell death processes of yeast cells. *Saccharomyces cerevisiae* yeast cells of the strains KFY417 (wild-type) and KFY437 (cdc48-mutant) were exposed to 900 or 872 MHz RF fields, with or without exposure to ultraviolet (UV) radiation, and incubated simultaneously with elevated temperature (+37°C) to induce apoptosis in the cdc48-mutated strain. The RF exposure was carried out in a special waveguide exposure chamber where the temperature of the cell cultures can be precisely controlled. Apoptosis was analyzed using the annexin V-FITC method utilizing flow cytometry. Amplitude modulated (217 pulses per second) RF exposure significantly enhanced UV induced apoptosis in cdc48-mutated cells, but no effect was observed in cells exposed to unmodulated fields at identical time-average specific absorption rates (SAR, 0.4 or 3.0 W/kg). The findings suggest that amplitude modulated RF fields, together with known damaging agents, can affect the cell death process in mutated yeast cells.

Mashevich M, Folkman D, Kesar A, Barbul A, Korenstein R, Jerby E, Avivi L, Exposure of human peripheral blood lymphocytes to electromagnetic fields associated with cellular phones leads to chromosomal instability. *Bioelectromagnetics* 24:82-90, 2003.

Whether exposure to radiation emitted from cellular phones poses a health hazard is at the focus of current debate. We have examined whether in vitro exposure of human peripheral blood lymphocytes (PBL) to continuous 830 MHz electromagnetic fields causes losses and gains of chromosomes (aneuploidy), a major “somatic mutation” leading to genomic instability and thereby to cancer. PBL were irradiated at different average absorption rates (SAR) in the range of 1.6-8.8 W/kg for 72 hr in an exposure system based on a parallel plate resonator at temperatures ranging from 34.5-37.5 °C. The averaged SAR and its distribution in the exposed tissue culture flask were determined by combining measurements and numerical analysis based on a finite element simulation code. A linear increase in chromosome 17 aneuploidy was observed as a function of the SAR value, demonstrating that this radiation has a genotoxic effect. The SAR dependent aneuploidy was accompanied by an abnormal mode of replication of the chromosome 17 region engaged in segregation (repetitive DNA arrays associated with the centromere), suggesting that epigenetic alterations are involved in the SAR dependent genetic toxicity. Control experiments (i.e., without any RF radiation) carried out in the temperature range of 34.5-38.5 °C showed that elevated temperature is not associated with either the genetic or epigenetic alterations observed following RF radiation - the increased levels of aneuploidy and the modification in replication of the centromeric DNA arrays. These findings indicate that the genotoxic effect of the electromagnetic radiation is elicited via a non-thermal pathway. Moreover, the fact that aneuploidy is a phenomenon known to increase the risk for cancer, should be taken into consideration in future evaluation of exposure guidelines.

Masuda H, Sanchez S, Dulou PE, Haro E, Anane R, Billaudel B, Leveque P, Veyret B. Effect of GSM-900 and -1800 signals on the skin of hairless rats. I: 2-hour acute exposures. *Int J Radiat Biol.* 82(9):669-674, 2006.

Purpose: The acute influence on the skin of non-ionizing electromagnetic fields in the radiofrequency (RF) range used in mobile telephony has not been widely studied to date. The purpose of this work was to determine whether the cells of hairless rat skin are affected by acute local exposure to Global System for Mobile Communication: GSM-900 or -1800 RadioFrequency Radiation (RFR). Materials and methods: Hairless female rats were exposed or sham-exposed for 2 h to GSM-900 or -1800 signals, using a loop-antenna located on the right part of the rats' back. The local Specific Absorption rate (SAR) at skin level was ca. 5 W/kg (5.8+/-0.4 and 4.8+/-0.4 W/kg at 900 and 1800 MHz, respectively). A skin biopsy was done at the end of the experiment not only at the location of exposure, but also on the symmetrical part of the back. Results: Analysis of skin sections using Hematoxylin Eosin Saffron (HES) coloration showed no difference in skin thickness or apparent cell toxicity (with no sign of cellular necrosis) among the animal groups. Histological analysis of the epidermis showed that the ratio between cells expressing the antigen Ki-67 (cellular proliferation marker) and the total number of cells remained within the range of normal proliferation ratio for the exposed side of the animal. No Ki-67 labelling was observed at the dermis level. Results on filaggrin, collagen and elastin levels also showed an insignificant influence of RFR. Conclusions: These results do not demonstrate any major physical and histological variations at skin level induced by RFR used in mobile telephony.

Masuda H, Ushiyama A, Hirota S, Wake K, Watanabe S, Yamanaka Y, Taki M, Ohkubo C. Effects of subchronic exposure to a 1439 MHz electromagnetic field on the microcirculatory parameters in rat brain. *In Vivo.* 21(4):563-570, 2007.

THE AIM of this study was to investigate whether repeated exposure to radio frequency electromagnetic field (RF-EMF) of 1439 MHz affects the cerebral microcirculation, including blood-brain barrier function, in a rat brain. MATERIALS AND METHODS: The head of the rat was exposed for four weeks (60 min/day, 5 days/week) to RF-EMF at 2.4 W/kg of brain averaged specific absorption rate (BASAR). Three microcirculatory parameters: blood-brain barrier permeability, leukocyte behavior and plasma velocity were measured before and after RF-EMF exposure using a closed cranial window method. RESULTS: No extravasation of intravenously injected dyes from pial venules was found at any BASAR level. No significant changes in the number of endothelial-adhering leukocytes after exposure were found. The plasma velocity remained constant within the physiological range through each exposure. CONCLUSION: These findings suggest that there were no effects on the cerebral microcirculation under the given RF-EMF exposure conditions.

Masuda H, Ushiyama A, Hirota S, Wake K, Watanabe S, Yamanaka Y, Taki M, Ohkubo C. Effects of acute exposure to a 1439 MHz electromagnetic field on the microcirculatory parameters in rat brain. *In Vivo*. 21(4):555-562, 2007.

THE AIM of this study was to determine the potential of radio-frequency electromagnetic fields (RF-EMF) to affect cerebral microcirculation, including blood-brain barrier function, in rat brain. MATERIALS AND METHODS: The head of the rat was exposed for 10 min to 1439 MHz RF-EMF having three intensity doses: 0.6, 2.4, 4.8 W/kg of brain averaged specific absorption rate (BASAR). Four microcirculatory parameters: blood-brain barrier permeability, leukocyte behavior, plasma velocity, and vessel diameter were measured before and after RF-EMF exposure using a closed cranial window method. RESULTS: No extravasation of intravenously injected dyes from pial venules was found at any BASAR level. No significant changes in the number of endothelial-adhering leukocytes after exposure were found. The hemodynamics indicated that the plasma velocities and vessel diameters remained constant within the physiological range throughout each exposure. CONCLUSION: These findings suggest that there were no effects on the cerebral microcirculation under the given RF-EMF exposure conditions.

Mausset A, de Seze R, Montpeyrroux F, Privat A. Effects of radiofrequency exposure on the GABAergic system in the rat cerebellum: clues from semi-quantitative immunohistochemistry. *Brain Res* 912(1):33-46, 2001.

The widespread use of cellular phones raises the problem of interaction of electromagnetic fields with the central nervous system (CNS). In order to measure these effects on neurotransmitter content in the CNS, we developed a protocol of neurotransmitter detection based on immunohistochemistry and image analysis. Gamma-vinyl-GABA (GVG), an inhibitor of the GABA-transaminase was injected in rats to increase GABA concentration in the CNS. The cellular GABA contents were then revealed by immunohistochemistry and semi-quantified by image analysis thanks to three parameters: optical density (O.D.), staining area, and number of positive cells. The increase in cerebellar GABA content induced by GVG 1200 mg/kg was reflected in these three parameters in the molecular and the granular layers. Therefore, control of immunohistochemistry parameters, together with appropriate image analysis, allowed both the location and the detection of variations in cellular neurotransmitter content. This protocol was used to investigate the effects of exposure to 900 MHz radiofrequencies on cerebellar GABA content. Both pulsed emission with a specific absorption rate (SAR) of 4 W/kg and continuous emission with high SAR (32 W/kg) were tested. We observed a selective diminution of the stained processes area in the Purkinje cell layer after exposure to pulsed radiofrequency and, in addition, a decrease in O.D. in the three cell layers after exposure to continuous waves. Whether this effect is, at least partly, due to a local heating of the tissues is not known. Overall, it appears that high energetic radiofrequency exposure induces a diminution in cellular GABA content in the cerebellum.

Mausset-Bonnefont AL, Hirbec H, Bonnefont X, Privat A, Vignon J, de Seze R. Acute exposure to GSM 900-MHz electromagnetic fields induces glial reactivity and biochemical modifications in the rat brain. *Neurobiol Dis*. 17(3):445-454, 2004.

The worldwide proliferation of mobile phones raises the question of the effects of 900-MHz electromagnetic fields (EMF) on the brain. Using a head-only exposure device in the rat, we showed that a 15-min exposure to 900-MHz pulsed microwaves at a high brain-averaged power of 6 W/kg induced a strong glial reaction in the brain. This effect, which suggests neuronal damage, was particularly pronounced in the striatum. Moreover, we observed significant and immediate effects on the K(d) and B(max) values of N-methyl-D-aspartate (NMDA) and GABA(A) receptors as well as on dopamine transporters. Decrease of the amount of NMDA receptors at the postsynaptic membrane is also reported. Although we showed that the rat general locomotor behavior was not significantly altered on the short term, our results provide the first evidence for rapid cellular and molecular alterations in the rat brain after an acute exposure to high power GSM (Global System for Mobile communication) 900-MHz microwaves.

Mazor R, Korenstein-Ilan A, Barbul A, Eshet Y, Shahadi A, Jerby E, Korenstein R. Increased levels of numerical chromosome aberrations after in vitro exposure of human peripheral blood lymphocytes to radiofrequency electromagnetic fields for 72 hours. *Radiat Res*. 169(1):28-37, 2008.

We investigated the effects of 72 h in vitro exposure of 10 human lymphocyte samples to radiofrequency electromagnetic fields (800 MHz, continuous wave) on genomic instability. The lymphocytes were exposed in a specially designed waveguide resonator at specific absorption rates (SARs) of 2.9 and 4.1 W/kg in a temperature range of 36-37 degrees C. The induced aneuploidy of chromosomes 1, 10, 11 and 17 was determined by interphase FISH using semi-automated image analysis. We observed increased levels of aneuploidy depending on the chromosome studied as well as on the level of exposure. In chromosomes 1 and 10, there was increased aneuploidy at the higher SAR, while for chromosomes 11 and 17, the increases were observed only for the lower SAR. Multisomy (chromosomal gains) appeared to be the primary contributor to the increased aneuploidy. The effect of temperature on the level of aneuploidy was examined over the range of 33.5-40 degrees C for 72 h with no statistically significant difference in the level of aneuploidy compared to 37 degrees C. These findings suggest the possible existence of an athermal effect of RF radiation that causes increased levels of aneuploidy. These results contribute to the assessment of potential health risks after continuous chronic exposure to RF radiation at SARs close to the current levels set by ICNIRP guidelines.

McNamee JP, Bellier PV, Gajda GB, Miller SM, Lemay EP, Lavallee BF, Marro L, Thansandote A. DNA Damage and Micronucleus Induction in Human Leukocytes after Acute In Vitro Exposure to a 1.9 GHz Continuous-Wave Radiofrequency Field. *Radiat Res* 158(4):523-533, 2002a.

Human blood cultures were exposed to a 1.9 GHz continuous-wave (CW) radiofrequency (RF) field for 2 h using a series of six circularly polarized, cylindrical waveguides. Mean specific absorption rates (SARs) of 0.0, 0.1, 0.26, 0.92, 2.4 and 10 W/kg were achieved, and the temperature within the cultures during a 2-h exposure was maintained at 37.0 +/- 0.5 degrees C. Concurrent negative (incubator) and positive (1.5 Gy (137)Cs gamma radiation) control cultures were run for each experiment. DNA damage was quantified immediately after RF-field exposure using the alkaline comet assay, and four parameters (tail ratio, tail moment, comet length and tail length) were used to assess DNA damage for each comet. No evidence of increased primary DNA damage was detected by any parameter for RF-field-exposed cultures at any SAR tested. The formation of micronuclei in the RF-field-exposed blood cell cultures was assessed using the cytokinesis-block micronucleus assay. There was no significant difference in the binucleated cell frequency, incidence of micronucleated binucleated cells, or total incidence of micronuclei between any of the RF-field-exposed cultures and the sham-exposed controls at any SAR tested. These results do not support the hypothesis that acute, nonthermalizing 1.9 GHz CW RF-field exposure causes DNA damage in cultured human leukocytes.

McNamee JP, Bellier PV, Gajda GB, Lavallee BF, Lemay EP, Marro L, Thansandote A. DNA Damage in Human Leukocytes after Acute In Vitro Exposure to a 1.9 GHz Pulse-Modulated Radiofrequency Field. *Radiat Res* 158(4):534-537, 2002b.

Blood cultures from human volunteers were exposed to an acute 1.9 GHz pulse-modulated radiofrequency (RF) field for 2 h using a series of six circularly polarized, cylindrical waveguides. Mean specific absorption rates (SARs) ranged from 0 to 10 W/kg, and the temperature within the cultures during the exposure was maintained at 37.0 +/- 0.5 degrees C. DNA damage was quantified in leukocytes by the alkaline comet assay and the cytokinesis-block micronucleus assay. When compared to the sham-treated controls, no evidence of increased primary DNA damage was detected by any parameter for any of the RF-field-exposed cultures when evaluated using the alkaline comet assay. Furthermore, no significant differences in the frequency of binucleated cells, incidence of micronucleated binucleated cells, or total incidence of micronuclei were detected between any of the RF-field-exposed cultures and the sham-treated control at any SAR tested. These results do not support the hypothesis that acute, nonthermalizing 1.9 GHz pulse-modulated RF-field exposure causes DNA damage in cultured human leukocytes.

McNamee JP, Bellier PV, Gajda GB, Lavallee BF, Marro L, Lemay E, Thansandote A. No Evidence for Genotoxic Effects from 24 h Exposure of Human Leukocytes to 1.9 GHz Radiofrequency Fields. *Radiat Res* 159(5):693-697, 2003.

McNamee, J. P., Bellier, P. V., Gajda, G. B., Lavallee, B. F., Marro, L., Lemay, E. and Thansandote, A. No Evidence for Genotoxic Effects from 24 h Exposure of Human Leukocytes to 1.9 GHz Radiofrequency Fields. *Radiat. Res.* 159, 693-697 (2003). The current study extends our previous investigations of 2-h radiofrequency (RF)-field exposures on genotoxicity in human blood cell cultures by examining the effect of 24-h continuous-wave (CW) and pulsed-wave (PW)

1.9 GHz RF-field exposures on both primary DNA damage and micronucleus induction in human leukocyte cultures. Mean specific absorption rates (SARs) ranged from 0 to 10 W/kg, and the temperature within the cultures was maintained at 37.0 +/- 1.0 degrees C for the duration of the 24-h exposure period. No significant differences in primary DNA damage were observed between the sham-treated controls and any of the CW or PW 1.9 GHz RF-field-exposed cultures when processed immediately after the exposure period by the alkaline comet assay. Similarly, no significant differences were observed in the incidence of micronuclei, incidence of micronucleated binucleated cells, frequency of binucleated cells, or proliferation index between the sham-treated controls and any of the CW or PW 1.9 GHz RF-field-exposed cultures. In conclusion, the current study found no evidence of 1.9 GHz RF-field-induced genotoxicity in human blood cell cultures after a 24-h exposure period.

Meo SA, Al-Drees AM. Mobile phone related-hazards and subjective hearing and vision symptoms in the Saudi population. *Int J Occup Med Environ Health*. 18(1):53-57, 2005

OBJECTIVES: Over the past decade utilization of mobile phones has dramatically increased. They are now an essential part of business, commerce, and communication, however, their use may lead to health problems. Therefore, the present study was designed to investigate a link between the use of mobile phones and hearing and vision symptoms in the Saudi population and also to contribute to the increase in social awareness of health problems associated with the use of these devices. **MATERIALS AND METHODS:** A total of 873 (57.04% of males and 39.86% of females) subjects using mobile phones were invited to participate in the presented study. A structured questionnaire was distributed among them to collect a detailed medical history. The Chi-square test was employed to observe the relationship between duration of calls and hearing and vision complaints. **RESULTS:** The present study showed an association between the use of mobile phones and hearing and vision complaints. About 34.59% of problems were related with impaired hearing, ear ache and/or warmth on the ear, and 5.04% of complaints with the decreased and/or blurred vision. **CONCLUSIONS:** It is concluded that the use of mobile phone is a health risk factor, and thus it is suggested that excessive use of mobile phones should be avoided and social awareness increased through health promotion activities, such as group discussions or public presentations and via electronic and printed media sources.

Meral I, Mert H, Mert N, Deger Y, Yoruk I, Yetkin A, Keskin S. Effects of 900-MHz electromagnetic field emitted from cellular phone on brain oxidative stress and some vitamin levels of guinea pigs. *Brain Res*. 2007 Jul 17; [Epub ahead of print]

This study was designed to demonstrate the effects of 900-MHz electromagnetic field (EMF) emitted from cellular phone on brain tissue and also blood malondialdehyde (MDA), glutathione (GSH), retinol (vitamin A), vitamin D(3) and tocopherol (vitamin E) levels, and catalase (CAT) enzyme activity of guinea pigs. Fourteen male guinea pigs, weighing 500-800 g were randomly divided into one of two experimental groups: control and treatment (EMF-exposed), each containing seven animals. Animals in treatment group were exposed to 890- to 915-MHz EMF (217-Hz pulse rate, 2-W maximum peak power, SAR 0.95 w/kg) of a cellular phone for 12 h/day (11-h 45-min stand-by and 15-min spiking mode) for 30 days. Control guinea pigs were housed in a separate room without exposing EMF of a cellular phone. Blood samples were collected through a cardiac puncture and brains were removed after decapitation for the biochemical analysis at the end of the 30 days of experimental period. It was found that the MDA level increased ($P<0.05$), GSH level and CAT enzyme activity decreased ($P<0.05$), and vitamins A, E and D(3) levels did not change ($P>0.05$) in the brain tissues of EMF-exposed guinea pigs. In addition, MDA, vitamins A, D(3) and E levels, and CAT enzyme activity increased ($P<0.05$), and GSH level decreased ($P<0.05$) in the blood of EMF-exposed guinea pigs. It was concluded that electromagnetic field emitted from cellular phone might produce oxidative stress in brain tissue of guinea pigs. However, more studies are needed to demonstrate whether these effects are harmful or/and affect the neural functions.

Merola P, Marino C, Lovisolo GA, Pinto R, Laconi C, Negroni A. Proliferation and apoptosis in a neuroblastoma cell line exposed to 900 MHz modulated radiofrequency field. *Bioelectromagnetics*. 2006 Jan 25; [Epub ahead of print]

The aim of this study was to examine whether a modulated radiofrequency of the type used in cellular phone communications at a specific absorption rate (SAR) higher than International Commission on Non-ionizing Radiation Protection (ICNIRP) reference level for occupational exposure, could elicit alterations on proliferation, differentiation,

and apoptosis processes in a neuroblastoma cell line. The cell line was exposed for 24, 48, and 72 h to 900 MHz radiofrequency and proliferation and differentiation were tested by WST-I assay and by a molecular analysis of specific markers, two oncogenes and a cytoskeleton protein, in exponential growth phase and in synchronized cell cultures. Apoptosis was evaluated by caspase activation analysis and by molecular detection of Poly (ADP-ribose) polymerase (PARP) cleavage. Combined exposures to radiofrequency and to the differentiative agent retinoic acid or to the apoptotic inducer camptothecin were carried out to test possible interference between electromagnetic field and chemical agents. Overall our data suggest that 900 MHz radiofrequency exposure up to 72 h does not induce significant alterations in the three principal cell activities in a neuroblastoma cell line.

Hansson Mild K, Hardell L, Carlberg M. Pooled analysis of two Swedish case-control studies on the use of mobile and cordless telephones and the risk of brain tumours diagnosed during 1997-2003. *Int J Occup Saf Ergon*. 13(1):63-71, 2007.

Here we present the pooled analysis of 2 case-control studies on the association of brain tumours with mobile phone use. Use of analogue cellular phones increased the risk for acoustic neuroma by 5%, 95% confidence interval (CI) = 2-9% per 100 hrs of use. The risk increased for astrocytoma grade III-IV with latency period with highest estimates using >10-year time period from first use of these phone types. The risk increased per one year of use of analogue phones by 10%, 95% CI = 6-14%, digital phones by 11%, 95% CI = 6-16%, and cordless phones by 8%, 95% CI = 5-12%. For all studied phone types OR for brain tumours, mainly acoustic neuroma and malignant brain tumours, increased with latency period, especially for astrocytoma grade III-IV.

Manti L, Braselmann H, Calabrese ML, Massa R, Pugliese M, Scampori P, Sicignano G, Grossi G. Effects of modulated microwave radiation at cellular telephone frequency (1.95 GHz) on X-ray-induced chromosome aberrations in human lymphocytes in vitro. *Radiat Res*. 169(5):575-583, 2008.

The case for a DNA-damaging action produced by radiofrequency (RF) signals remains controversial despite extensive research. With the advent of the Universal Mobile Telecommunication System (UMTS) the number of RF-radiation-exposed individuals is likely to escalate. Since the epigenetic effects of RF radiation are poorly understood and since the potential modifications of repair efficiency after exposure to known cytotoxic agents such as ionizing radiation have been investigated infrequently thus far, we studied the influence of UMTS exposure on the yield of chromosome aberrations induced by X rays. Human peripheral blood lymphocytes were exposed in vitro to a UMTS signal (frequency carrier of 1.95 GHz) for 24 h at 0.5 and 2.0 W/kg specific absorption rate (SAR) using a previously characterized waveguide system. The frequency of chromosome aberrations was measured on metaphase spreads from cells given 4 Gy of X rays immediately before RF radiation or sham exposures by fluorescence in situ hybridization. Unirradiated controls were RF-radiation- or sham-exposed. No significant variations due to the UMTS exposure were found in the fraction of aberrant cells. However, the frequency of exchanges per cell was affected by the SAR, showing a small but statistically significant increase of 0.11 exchange per cell compared to 0 W/kg SAR. We conclude that, although the 1.95 GHz signal (UMTS modulated) does not exacerbate the yield of aberrant cells caused by ionizing radiation, the overall burden of X-ray-induced chromosomal damage per cell in first-mitosis lymphocytes may be enhanced at 2.0 W/kg SAR. Hence the SAR may either influence the repair of X-ray-induced DNA breaks or alter the cell death pathways of the damage response.

Moisesescu MG, Leveque P, Verjus MA, Kovacs E, Mir LM. 900 MHz modulated electromagnetic fields accelerate the clathrin-mediated endocytosis pathway. *Bioelectromagnetics*, 2008 Dec 12 [Epub ahead of print]

We report new data regarding the molecular mechanisms of GSM-induced increase of cell endocytosis rate. Even though endocytosis represents an important physical and biological event for cell physiology, studies on modulated electromagnetic fields (EMF) effects on this process are scarce. In a previous article, we showed that fluid phase endocytosis rate increases when cultured cells are exposed to 900 MHz EMF similar to mobile phones' modulated GSM signals (217 Hz repetition frequency, 576 micros pulse width) and to electric pulses similar to the GSM electrical component. Trying to distinguish the mechanisms sustaining this endocytosis stimulation, we exposed murine melanoma cells to Lucifer Yellow (LY) or to GSM-EMF/electric pulses in the presence of drugs inhibiting the clathrin- or the

caveolin-dependent endocytosis. Experiments were performed at a specific absorption rate (SAR) of 3.2 W/kg in a wire patch cell under homogeneously distributed EMF field and controlled temperature (in the range of 28.5-29.5 degrees C). Thus, the observed increase in LY uptake was not a thermal effect. Chlorpromazine and ethanol, but not Filipin, inhibited this increase. Therefore, the clathrin-dependent endocytosis is stimulated by the GSM-EMF, suggesting that the cellular mechanism affected by the modulated EMF involves vesicles that detach from the cell membrane, mainly clathrin-coated vesicles.

Moisescu MG, Leveque P, Bertrand JR, Kovacs E, Mir LM. Microscopic observation of living cells during their exposure to modulated electromagnetic fields. *Bioelectrochemistry* 74(1) 9-15, 2008.

Studying cell behaviour under irradiation with radiofrequency electromagnetic fields (RF-EMF) is often impeded by the difficulty to monitor cell characteristics during irradiation. Here we report the design and the application of a complete device for continuous microscopic observation of cells exposed to modulated EMF similar to mobile phones signals. The system allows the follow up of cell progression into mitosis under controlled temperature and CO(2) environment. Protocols are proposed in which the same cells are the controls before and after the EMF exposure and we demonstrate the interest of the "before exposure" controls. The exposure system was validated by cell endocytosis measurements. While the endocytosis rate was increased, no alteration of mitosis progression and mitosis duration was observed in cells exposed to 900 MHz modulated EMF for 1 h, at 30 degrees C and at a Specific Absorption Rate of 2.2 W/kg.

Monfrecola G, Moffa G, Procaccini EM. Non-ionizing electromagnetic radiations, emitted by a cellular phone, modify cutaneous blood flow. *Dermatology*. 207(1):10-14, 2003.

BACKGROUND: Our surroundings are full of non-ionizing electromagnetic radiation (EMR) of different frequency and power. The non-ionizing EMRs emitted by television, computer and cellular phone (CF) sets have been increasing over the past few years. OBJECTIVE: The aim of our study was to assess the effects of non-ionizing EMRs (frequency $3 \times 10(8)$ to $3 \times 10(11)$ Hz), emitted by CFs, on cutaneous blood flow in healthy volunteers. METHODS: Thirty healthy volunteers (14 male and 16 female; age: 18-53 years) entered the study. Measurements of cutaneous blood flow were taken under standard conditions (temperature and humidity), using a laser Doppler He-Ne flowmeter that was applied to the ear skin by an optical fibre probe. Microflow values were recorded without CF contact with the skin (T0), with the CF turned off but in contact with the ear skin (T1), with CF contact and turned on (T2), with CF contact, turned on and receiving (T3). The microflow values were also recorded backwards: with CF contact and set turned on (T4), with CF contact and turned off (T5), without CF contact (T6). RESULTS: The mean value of basal microflow (T0), expressed as perfusion units (PU), was 51.26 ± 11.93 PU. During the T1 phase, the microflow increase was 61.38%; in T2 it was 131.74%, in T3 157.67%, in T4 139.21% and in T5 122.90%; in T6, the microflow value was 57.58 ± 10 PU (similar to the basal microflow). Statistically significant cutaneous microflow values ($p < 0.050$) were observed comparing the T1 to T5 values with basal microflow (T0). Furthermore, in comparison with T1 values (CF turned off in contact with the ear skin), the T2, T3 and T4 data were statistically significant (T2 vs. T1: $t = 7.763$ with $p < 0.050$; T3 vs. T1: $t = 9.834$ with $p < 0.050$; T4 vs. T1: $t = 8.885$ with $p < 0.050$).

Monnery PM, Srouji EI, Bartlett J. Is cochlear outer hair cell function affected by mobile telephone radiation? *Clin Otolaryngol* 29(6):747-749, 2004.

Mobile telephones emit high-frequency pulsed electromagnetic fields (PEMF). These are known to have measurable biological effects, and possible effects on the auditory system. Otoacoustic emissions give an indication of the functional state of the auditory system. Otoacoustics are known to be highly specific for the individual when the test pulse is identical. In this way, subtle changes in the ear can be detected. We investigated whether there is a measurable effect on Otoacoustic emissions from PEMF radiation. A total of 12 volunteers were recruited who had normal hearing; confirmed by pure tone audiometry. An Otoacoustic emission trace was obtained. The test subjects were exposed to a mobile telephone that was placed over the test ears mastoid process. The subjects had Otoacoustic emissions measured without the telephone and again on receive and transmit. There was no change in the trace signature during the test. There was no

statistically significant change in the trace figures. This would indicate that PEMF from commonly available hand held mobile telephones have no measurable effect on the outer hair cell function during the time of use.

Mora R, Crippa B, Mora F, Dellepiane M. A study of the effects of cellular telephone microwave radiation on the auditory system in healthy men. *Ear Nose Throat J.* 85(3):160, 162-163, 2006.

We conducted a study of the effects of mobile cellular telephone microwave radiation on the auditory system in 20 healthy men. After the subjects underwent baseline measurements of transient evoked otoacoustic emission (TEOAE) and auditory brainstem response (ABR), they participated in three sessions of exposure to an electromagnetic field of 900 to 1,800 MHz produced by a cellular phone. Sessions ranged from 15 to 30 minutes in length. TEOAE and ABR were again measured after or during each exposure. Throughout the study, no significant changes in either measurement were noted. We conclude that the use of cellular phones does not alter the auditory system in the short-term.

Morrissey JJ, Raney S, Heasley E, Rathinavelu P, Dauphinee M, Fallon JH, IRIDIUM exposure increases c-fos expression in the mouse brain only at levels which likely result in tissue heating. *Neuroscience* 92(4):1539-1546, 1999.

With the rapid development of wireless communication technology over the last 20 years, there has been some public concern over possible health effects of long-term, low-level radiofrequency exposure from cellular telephones. As an initial step in compiling a database for risk analysis by government agencies, the effects of 1-h exposure of mice to a 1.6-GHz radiofrequency signal, given as either a continuous wave or pulse modulated at 11 Hz with a duty cycle of 4:1 and a pulse duration of 9.2 ms (IRIDIUM), on c-fos gene expression in the brain was investigated. The IRIDIUM signal is the operating frequency for a ground-to-satellite-to-ground cellular communications web which has recently become fully operational, and was named as such due to the original designed employment of the same number of low orbiting satellites as there are electrons orbiting the nucleus of an iridium atom. The expression of c-fos was not significantly elevated in the brains of mice until exposure levels exceeded six times the peak dose and 30 times the whole body average dose as maximal cellular telephone exposure limits in humans. Higher level exposure using either continuous wave (analog) or IRIDIUM signals elevated c-fos to a similar extent, suggesting no obvious pulsed modulation-specific effects. The pattern of c-fos elevation in limbic cortex and subcortex areas at higher exposure levels is most consistent with a stress response due to thermal perception coupled with restraint and/or neuron activity near thermoregulatory regions, and not consistent with any direct interaction of IRIDIUM energy with brain tissue.

Mortazavi SM, Daiee E, Yazdi A, Khiabani K, Kavousi A, Vazirinejad R, Behnejad B, Ghasemi M, Mood MB. Mercury release from dental amalgam restorations after magnetic resonance imaging and following mobile phone use. *Pak J Biol Sci.* 11(8):1142-1146, 2008.

In the 1st phase of this study, thirty patients were investigated. Five milliliter stimulated saliva was collected just before and after MRI. The magnetic flux density was 0.23 T and the duration of exposure of patients to magnetic field was 30 minutes. In the 2nd phase, fourteen female healthy University students who had not used mobile phones before the study and did not have any previous amalgam restorations were investigated. Dental amalgam restoration was performed for all 14 students. Their urine samples were collected before amalgam restoration and at days 1, 2, 3 and 4 after restoration. The mean \pm SD saliva Hg concentrations of the patients before and after MRI were 8.6 ± 3.0 and 11.3 ± 5.3 microg L(-1), respectively ($p < 0.01$). A statistical significant ($p < 0.05$) higher concentration was observed in the students used mobile phone. The mean \pm SE urinary Hg concentrations of the students who used mobile phones were 2.43 ± 0.25 , 2.71 ± 0.27 , 3.79 ± 0.25 , 4.8 ± 0.27 and 4.5 ± 0.32 microg L(-1) before the amalgam restoration and at days 1, 2, 3 and 4, respectively. Whereas the respective Hg concentrations in the controls, were 2.07 ± 0.22 , 2.34 ± 0.30 , 2.51 ± 0.25 , 2.66 ± 0.24 and 2.76 ± 0.32 microg L(-1). It appears that MRI and microwave radiation emitted from mobile phones significantly release mercury from dental amalgam restoration. Further research is needed to clarify whether other common sources of electromagnetic field exposure may cause alterations in dental amalgam and accelerate the release of mercury.

Mousavy SJ, Riazi GH, Kamarei M, Aliakbarian H, Sattarahmady N, Sharifizadeh A, Safarian S, Ahmad F, Moosavi-Movahedi AA. Effects of mobile phone radiofrequency on the structure and function of the normal human hemoglobin. *Int J Biol Macromol.* 44(3):278-285, 2009

Widespread use of mobile phones has increased the human exposure to electromagnetic fields (EMFs). It is required to investigate the effect of EMFs on the biological systems. In this paper the effect of mobile phone RF (910MHz and 940 MHz) on structure and function of HbA was investigated. Oxygen affinity was measured by sodium dithionite with UV-vis spectrophotometer. Structural changes were studied by circular dichroism and fluorescence spectroscopy. The results indicated that mobile phone EMFs altered oxygen affinity and tertiary structure of HbA. Furthermore, the decrease of oxygen affinity of HbA corresponded to the EMFs intensity and time of exposure.

Moustafa YM, Moustafa RM, Belacy A, Abou-El-Ela SH, Ali FM.

Effects of acute exposure to the radiofrequency fields of cellular phones on plasma lipid peroxide and antioxidase activities in human erythrocytes. *J Pharm Biomed Anal* 26(4):605-608, 2001.

Radiofrequency fields of cellular phones may affect biological systems by increasing free radicals, which appear mainly to enhance lipid peroxidation, and by changing the antioxidase activities of human blood thus leading to oxidative stress. To test this, we have investigated the effect of acute exposure to radiofrequency fields of commercially available cellular phones on some parameters indicative of oxidative stress in 12 healthy adult male volunteers. Each volunteer put the phone in his pocket in standby position with the keypad facing the body. The parameters measured were lipid peroxide and the activities of superoxide dismutase (SOD), total glutathione peroxidase (GSH-Px) and catalase. The results obtained showed that the plasma level of lipid peroxide was significantly increased after 1, 2 and 4 h of exposure to radiofrequency fields of the cellular phone in standby position. Moreover, the activities of SOD and GSH-Px in human erythrocytes showed significant reduction while the activity of catalase in human erythrocytes did not decrease significantly. These results indicate that acute exposure to radiofrequency fields of commercially available cellular phones may modulate the oxidative stress of free radicals by enhancing lipid peroxidation and reducing the activation of SOD and GSH-Px, which are free radical scavengers. Therefore, these results support the interaction of radiofrequency fields of cellular phones with biological systems.

Muscat JE, Malkin MG, Thompson S, Shore RE, Stellman SD, McRee D, Neugut AI, Wynder EL, Handheld cellular telephone use and risk of brain cancer. *JAMA* 284(23):3001-3007, 2000.

CONTEXT: A relative paucity of data exist on the possible health effects of using cellular telephones. OBJECTIVE: To test the hypothesis that using handheld cellular telephones is related to the risk of primary brain cancer. DESIGN AND SETTING: Case-control study conducted in 5 US academic medical centers between 1994 and 1998 using a structured questionnaire. PATIENTS: A total of 469 men and women aged 18 to 80 years with primary brain cancer and 422 matched controls without brain cancer. MAIN OUTCOME MEASURE: Risk of brain cancer compared by use of handheld cellular telephones, in hours per month and years of use. RESULTS: The median monthly hours of use were 2.5 for cases and 2.2 for controls. Compared with patients who never used handheld cellular telephones, the multivariate odds ratio (OR) associated with regular past or current use was 0.85 (95% confidence interval [CI], 0.6-1.2). The OR for infrequent users (<0.72 h/mo) was 1.0 (95% CI, 0.5-2.0) and for frequent users (>10.1 h/mo) was 0.7 (95% CI, 0.3-1.4). The mean duration of use was 2.8 years for cases and 2.7 years for controls; no association with brain cancer was observed according to duration of use ($P = .54$). In cases, cerebral tumors occurred more frequently on the same side of the head where cellular telephones had been used (26 vs 15 cases; $P = .06$), but in the cases with temporal lobe cancer a greater proportion of tumors occurred in the contralateral than ipsilateral side (9 vs 5 cases; $P = .33$). The OR was less than 1.0 for all histologic categories of brain cancer except for uncommon neuroepitheliomatous cancers (OR, 2.1; 95% CI, 0.9-4.7). CONCLUSIONS: Our data suggest that use of handheld cellular telephones is not associated with risk of brain cancer, but further studies are needed to account for longer induction periods, especially for slow-growing tumors with neuronal features.

Muscat JE, Malkin MG, Shore RE, Thompson S, Neugut AL, Stellman SD, Bruce J. Handheld cellular telephones and risk of acoustic neuroma. *Neurology* 58:1304-1306, 2002.

The hypothesis that intracranial energy deposition from handheld cellular telephones causes acoustic neuroma was tested in an epidemiologic study of 90 patients and 86 control subjects. The relative risk was 0.9 ($p = 0.07$) and did not vary significantly by the frequency, duration, and lifetime hours of use. In patients who used cellular telephones, the tumor occurred more often on the contralateral than ipsilateral side of the head. Further efforts should focus on potentially longer induction periods.

Nakamura H, Matsuzaki I, Hatta K, Nobukuni Y, Kambayashi Y, Ogino K. Nonthermal effects of mobile-phone frequency microwaves on uteroplacental functions in pregnant rats. *Reprod Toxicol* 2003 17(3):321-326, 2003.

Exposure to high-density microwaves can cause detrimental effects on the testis, eye, and other tissues, and induce significant biologic changes through thermal actions. To examine nonthermal effect of continuous wave (CW) 915MHz microwaves used in cellular phones, we compared the effects of microwaves with those of heat. Thirty-six pregnant rats were assigned to six groups: rats exposed to microwaves at 0.6 or 3mW/cm(2) incident power density at 915MHz for 90min, rats immersed in water at 38 or 40 degrees C, which induces about the same increase in colonic temperature of 1.0 or 3.5 degrees C as 0.6 or 3mW/cm(2) microwaves, respectively; rats immersed in water at 34 degrees C, which is considered to be thermoneutral; and control rats. We identified significant differences in the uteroplacental circulation, and in placental endocrine and immune functions between pregnant rats immersed in water at 34 and 38 degrees C, but not between rats immersed at 38 degrees C and those exposed to microwaves at 0.6mW/cm(2). By contrast, we observed significant decreases in uteroplacental blood flow and estradiol in rats exposed to microwaves at 3mW/cm(2) as compared with those immersed in water at 40 degrees C. These results suggest microwaves at 0.6mW/cm(2) at 915MHz, equal to a specific absorption rate (SAR) of 0.4W/kg, which is the maximum permissible exposure level recommended by the American National Standards Institute (ANSI), do not exert nonthermal effects on blood estradiol and progesterone, on splenic natural killer cell activity, on the uteroplacental circulation.

Nam KC, Kim SW, Kim SC, Kim DW. Effects of RF exposure of teenagers and adults by CDMA cellular phones. *Bioelectromagnetics*. 27(7):509-514, 2006.

Many cellular phone provocation studies have been conducted since the question of increased health risk from extended usage of cellular phones became a social issue. Internationally, most studies have been conducted regarding the effects of GSM cellular phones on blood pressure and heart rate of adult volunteers. On the other hand, very few provocation studies have been conducted regarding the physiological effects of CDMA phones on teenagers. In this study, two volunteer groups consisting of 21 teenagers and 21 adults were exposed to 300 mW of radio frequency (RF) electromagnetic field emitted by a CDMA cellular phone for half an hour. Physiological parameters such as systolic and diastolic blood pressures, heart rate, respiration rate, and skin resistance were simultaneously measured. All the parameters for both groups were unaffected during the exposure except for decreased skin resistance of the teenager group ($P < .0001$). For the regrouped 23 male and 19 female subjects, all the parameters for both groups were unaffected during the exposure except for decreased skin resistance of the male subjects ($P = .0026$). Those resistances at 10 min after the terminated exposure returned to the resistances at rest regardless of the different groups of age and sex.

Narayanan SN, Kumar RS, Potu BK, Nayak S, Mailankot M. Spatial memory performance of Wistar rats exposed to mobile phone. *Clinics*. 64(3):231-234, 2009.

INTRODUCTION: With the tremendous increase in number of mobile phone users world wide, the possible risks of this technology have become a serious concern. **OBJECTIVE:** We tested the effects of mobile phone exposure on spatial memory performance. **MATERIALS AND METHODS:** Male Wistar rats (10-12 weeks old) were exposed to 50 missed calls/day for 4 weeks from a GSM (900/1800 MHz) mobile phone in vibratory mode (no ring tone). After the experimental period, the animals were tested for spatial memory performance using the Morris water maze test. **RESULTS:** Both phone exposed and control animals showed a significant decrease in escape time with training. Phone exposed animals had significantly (approximately 3 times) higher mean latency to reach the target quadrant and spent significantly (approximately 2 times) less time in the target quadrant than age- and sex-matched controls. **CONCLUSION:** Mobile phone exposure affected the acquisition of learned responses in Wistar rats. This in turn points to the poor spatial navigation and the object place configurations of the phone-exposed animals.

Nasta F, Prisco MG, Pinto R, Lovisolo GA, Marino C, Pioli C. Effects of GSM-modulated radiofrequency electromagnetic fields on B-cell peripheral differentiation and antibody production. Radiat Res. 165(6):664-670, 2006.

We examined the effects of in vivo exposure to a GSM-modulated 900 MHz RF field on B-cell peripheral differentiation and antibody production in mice. Our results show that exposure to a whole-body average specific absorption rate (SAR) of 2 W/kg, 2 h/day for 4 consecutive weeks does not affect the frequencies of differentiating transitional 1 (T1) and T2 B cells or those of mature follicular B and marginal zone B cells in the spleen. IgM and IgG serum levels are also not significantly different among exposed, sham-exposed and control mice. B cells from these mice, challenged in vitro with LPS, produce comparable amounts of IgM and IgG. Moreover, exposure of immunized mice to RF fields does not change the antigen-specific antibody serum level. Interestingly, not only the production of antigen-specific IgM but also that of IgG (which requires T-B-cell interaction) is not affected by RF-field exposure. This indicates that the exposure does not alter an ongoing in vivo antigen-specific immune response. In conclusion, our results do not indicate any effects of GSM-modulated RF radiation on the B-cell peripheral compartment and antibody production and thus provide no support for health-threatening effects.

Nieto-Hernandez R, Rubin GJ, Cleare AJ, Weinman JA, Wessely S.

Can evidence change belief? Reported mobile phone sensitivity following individual feedback of an inability to discriminate active from sham signals. J Psychosom Res. 65(5):453-460, 2008.

OBJECTIVE: In this study, we tested whether providing individuals, who described being sensitive to mobile phone signals, with accurate feedback about their ability to discriminate an active mobile phone signal from a sham signal had any impact on their subsequent symptom levels or their perceived sensitivity to mobile phones. **METHODS:** Sixty-nine participants who reported sensitivity to mobile phones took part in a double-blind, placebo-controlled provocation study. Perceived sensitivity to mobile phones was assessed using a version of the Sensitive Soma Assessment Scale (SSAS) and the severity of any symptoms attributed to mobile phones was recorded. Both the overall ("negative") findings of the provocation study and the participant's own individual results ("correct" or "incorrect" at detecting a mobile phone signal) were then described to them. Six months later, perceived sensitivity and symptom severity were measured again. **RESULTS:** Fifty-eight participants (84%) received feedback and participated in the 6-month follow-up. No significant differences in SSAS scores or in symptom severity scores were found between individuals told that they were correct (n=31) or incorrect (n=27) in their ability to detect mobile phone signals in the provocation study. **CONCLUSION:** The provision of accurate feedback was insufficient to change attributions or reduce symptoms in this study. However, an overtly negative reaction to feedback was not observed among most participants, and some participants were willing to consider that factors other than electromagnetic field may be relevant in causing or exacerbating their symptoms. Discussing possible psychological factors with electromagnetic hypersensitivity patients may be beneficial for some.

Nikolova T, Czyz J, Rolletschek A, Blyszczuk P, Fuchs J, Jovtchev G, Schuderer J, Kuster N, Wobus AM.

Electromagnetic fields affect transcript levels of apoptosis-related genes in embryonic stem cell-derived neural progenitor cells. ASEB J. 19(12):1686-1688, 2005.

Mouse embryonic stem (ES) cells were used as an experimental model to study the effects of electromagnetic fields (EMF). ES-derived nestin-positive neural progenitor cells were exposed to extremely low frequency EMF simulating power line magnetic fields at 50 Hz (ELF-EMF) and to radiofrequency EMF simulating the Global System for Mobile Communication (GSM) signals at 1.71 GHz (RF-EMF). Following EMF exposure, cells were analyzed for transcript levels of cell cycle regulatory, apoptosis-related, and neural-specific genes and proteins; changes in proliferation; apoptosis; and cytogenetic effects. Quantitative RT-PCR analysis revealed that ELF-EMF exposure to ES-derived neural cells significantly affected transcript levels of the apoptosis-related bcl-2, bax, and cell cycle regulatory "growth arrest DNA damage inducible" GADD45 genes, whereas mRNA levels of neural-specific genes were not affected. RF-EMF exposure of neural progenitor cells resulted in down-regulation of neural-specific Nurr1 and in up-regulation of bax and GADD45 mRNA levels. Short-term RF-EMF exposure for 6 h, but not for 48 h, resulted in a low and transient increase of DNA double-strand breaks. No effects of ELF- and RF-EMF on mitochondrial function, nuclear apoptosis, cell proliferation, and chromosomal alterations were observed. We may conclude that EMF exposure of ES-derived neural progenitor cells transiently affects the transcript level of genes related to apoptosis and cell cycle control. However, these

responses are not associated with detectable changes of cell physiology, suggesting compensatory mechanisms at the translational and posttranslational level.

Nittby H, Grafström G, Tian DP, Malmgren L, Brun A, Persson BR, Salford LG, Eberhardt J. Cognitive impairment in rats after long-term exposure to GSM-900 mobile phone radiation. *Bioelectromagnetics*. 2007 Nov 28 [Epub ahead of print]

Considering the frequent use of mobile phones, we have directed attention to possible implications on cognitive functions. In this study we investigated in a rat model the long-term effects of protracted exposure to Global System for Mobile Communication-900 MHz (GSM-900) radiation. Out of a total of 56 rats, 32 were exposed for 2 h each week for 55 weeks to radio-frequency electromagnetic radiation at different SAR levels (0.6 and 60 mW/kg at the initiation of the experimental period) emitted by a (GSM-900) test phone. Sixteen animals were sham exposed and eight animals were cage controls, which never left the animal house. After this protracted exposure, GSM-900 exposed rats were compared to sham exposed controls. Effects on exploratory behaviour were evaluated in the open-field test, in which no difference was seen. Effects on cognitive functions were evaluated in the episodic-like memory test. In our study, GSM exposed rats had impaired memory for objects and their temporal order of presentation, compared to sham exposed controls ($P = 0.02$). Detecting the place in which an object was presented was not affected by GSM exposure. Our results suggest significantly reduced memory functions in rats after GSM microwave exposure ($P = 0.02$).

Nittby H, Brun A, Eberhardt J, Malmgren L, Persson BR, Salford LG. Increased blood-brain barrier permeability in mammalian brain 7 days after exposure to the radiation from a GSM-900 mobile phone. *Pathophysiology*. 2009 Apr 1. [Epub ahead of print]

Microwaves were for the first time produced by humans in 1886 when radio waves were broadcasted and received. Until then microwaves had only existed as a part of the cosmic background radiation since the birth of universe. By the following utilization of microwaves in telegraph communication, radars, television and above all, in the modern mobile phone technology, mankind is today exposed to microwaves at a level up to 10(20) times the original background radiation since the birth of universe. Our group has earlier shown that the electromagnetic radiation emitted by mobile phones alters the permeability of the blood-brain barrier (BBB), resulting in albumin extravasation immediately and 14 days after 2h of exposure. In the background section of this report, we present a thorough review of the literature on the demonstrated effects (or lack of effects) of microwave exposure upon the BBB. Furthermore, we have continued our own studies by investigating the effects of GSM mobile phone radiation upon the blood-brain barrier permeability of rats 7 days after one occasion of 2h of exposure. Forty-eight rats were exposed in TEM-cells for 2h at non-thermal specific absorption rates (SARs) of 0mW/kg, 0.12mW/kg, 1.2mW/kg, 12mW/kg and 120mW/kg. Albumin extravasation over the BBB, neuronal albumin uptake and neuronal damage were assessed. Albumin extravasation was enhanced in the mobile phone exposed rats as compared to sham controls after this 7-day recovery period (Fisher's exact probability test, $p=0.04$ and Kruskal-Wallis, $p=0.012$), at the SAR-value of 12mW/kg (Mann-Whitney, $p=0.007$) and with a trend of increased albumin extravasation also at the SAR-values of 0.12mW/kg and 120mW/kg. There was a low, but significant correlation between the exposure level (SAR-value) and occurrence of focal albumin extravasation ($r(s)=0.33$; $p=0.04$). The present findings are in agreement with our earlier studies where we have seen increased BBB permeability immediately and 14 days after exposure. We here discuss the present findings as well as the previous results of altered BBB permeability from our and other laboratories.

Nylund R, Leszczynski D. Proteomics analysis of human endothelial cell line EA.hy926 after exposure to GSM 900 radiation. *Proteomics* 4:1359-1365, 2004.

The human endothelial cell line EA.hy926 was exposed to mobile phone radiation and the effect on protein expression was examined using two-dimensional electrophoresis (2-DE). Up to 38 various proteins have statistically significantly altered their expression levels following the irradiation. Four proteins were identified with matrix-assisted laser desorption/ionization-mass spectrometry (MALDI-MS). Two of the affected proteins were determined to be isoforms of cytoskeletal vimentin. This finding supports our earlier presented working hypothesis which indicated that the mobile phone radiation might affect the cytoskeleton and might have an effect on the physiological functions that are regulated by the cytoskeleton.

Nylund R, Leszczynski D. Mobile phone radiation causes changes in gene and protein expression in human endothelial cell lines and the response seems to be genome- and proteome-dependent. *Proteomics*. 2006 Jul 28; [Epub ahead of print]

We have examined in vitro cell response to mobile phone radiation (900 MHz GSM signal) using two variants of human endothelial cell line: EA.hy926 and EA.hy926v1. Gene expression changes were examined in three experiments using cDNA Expression Arrays and protein expression changes were examined in ten experiments using 2-DE and PDQuest software. Obtained results show that gene and protein expression were altered, in both examined cell lines, in response to one hour mobile phone radiation exposure at an average specific absorption rate of 2.8 W/kg. However, the same genes and proteins were differently affected by the exposure in each of the cell lines. This suggests that the cell response to mobile phone radiation might be genome- and proteome-dependent. Therefore, it is likely that different types of cells and from different species might respond differently to mobile phone radiation or might have different sensitivity to this weak stimulus. Our findings might also explain, at least in part, the origin of discrepancies in replication studies between different laboratories.

Oberto G, Rolfo K, Yu P, Carbonatto M, Peano S, Kuster N, Ebert S, Tofani S. Carcinogenicity Study of 217 Hz Pulsed 900 MHz Electromagnetic Fields in Pim1 Transgenic Mice. *Radiat Res*. 168(3):316-326, 2007.

In an 18-month carcinogenicity study, Pim1 transgenic mice were exposed to pulsed 900 MHz (pulse width: 0.577 ms; pulse repetition rate: 217 Hz) radiofrequency (RF) radiation at a whole-body specific absorption rate (SAR) of 0.5, 1.4 or 4.0 W/kg [uncertainty ($k = 2$): 2.6 dB; lifetime variation ($k = 1$): 1.2 dB]. A total of 500 mice, 50 per sex per group, were exposed, sham-exposed or used as cage controls. The experiment was an extension of a previously published study in female Pim1 transgenic mice conducted by Repacholi et al. (*Radiat. Res.* 147, 631-640, 1997) that reported a significant increase in lymphomas after exposure to the same 900 MHz RF signal. Animals were exposed for 1 h/day, 7 days/week in plastic tubes similar to those used in inhalation studies to obtain well-defined uniform exposure. The study was conducted blind. The highest exposure level (4 W/kg) used in this study resulted in organ-averaged SARs that are above the peak spatial SAR limits allowed by the ICNIRP (International Commission on Non-ionizing Radiation Protection) standard for environmental exposures. The whole-body average was about three times greater than the highest average SAR reported in the earlier study by Repacholi et al. The results of this study do not suggest any effect of 217 Hz-pulsed RF-radiation exposure (pulse width: 0.577 ms) on the incidence of tumors at any site, and thus the findings of Repacholi et al. were not confirmed. Overall, the study shows no effect of RF radiation under the conditions used on the incidence of any neoplastic or non-neoplastic lesion, and thus the study does not provide evidence that RF radiation possesses carcinogenic potential.

Ofstedal G, Wilen J, Sandstrom M, Mild KH, Symptoms experienced in connection with mobile phone use. *Occup Med (Lond)* 50(4):237-245, 2000.

Many people in Norway and Sweden reported headaches, fatigue, and other symptoms experienced in connection with the use of a mobile phone (MP). Therefore, we initiated a cross-sectional epidemiological study among 17,000 people, all using an MP in their job. Thirty-one percent of the respondents in Norway and 13% of those in Sweden had experienced at least one symptom in connection with MP use. Next to the sensations of warmth on the ear and behind/around the ear, burning sensations in the facial skin and headaches were most commonly reported. Most symptoms usually began during or within half an hour after the call and lasted for up to 2 h. Relatively few had consulted a physician or been on sick leave because of the symptoms, but about 45% among those with an MP attributed symptom had taken steps to reduce the symptom. These results suggest an awareness of the symptoms, but not necessarily a serious health problem.

Ofstedal G, Straume A, Johnsson A, Stovner L. Mobile phone headache: a double blind, sham-controlled provocation study. *Cephalalgia*. 2007 Mar 14; [Epub ahead of print]

The objective was to test whether exposure to radio frequency (RF) fields from mobile phones may cause head pain or discomfort and whether it may influence physiological variables in individuals attributing symptoms to mobile phones, but not to electromagnetic fields in general. Seventeen eligible individuals, who experienced these symptoms in an open provocation test, took part in a double-blind, randomized provocation study with cross-over design. Sixty-five pairs of sham and mobile phone RF exposures were conducted. The increase in pain or discomfort (visual analogue scales) in RF sessions was 10.1 and in sham sessions 12.6 ($P = 0.30$). Changes in heart rate or blood pressure were not related to the

type of exposure (P: 0.30-0.88). The study gave no evidence that RF fields from mobile phones may cause head pain or discomfort or influence physiological variables. The most likely reason for the symptoms is a placebo effect.

Oktay MF, Dasdag S. Effects of intensive and moderate cellular phone use on hearing function. *Electromagn Biol Med.* 25(1):13-21, 2006.

The purpose of this study is to investigate the effects of radiation emitted by mobile phones on the hearing of users. The study was carried out on three groups: 1) 20 men who have used a cellular phone frequently and spoken approximately 2 h per day for four years; 2) 20 men who have used a cellular phone for 10-20 min per day for four years; and 3) 20 healthy men who have never used a cellular phone (the control group). Brainstem evoked response audiometric (BERA) and pure tone audiometric (PTA) methods were used to measure the effects of exposure on hearing function of the subjects. In BERA measurements, I-III, III-V, and I-V interpeak latencies were evaluated. Interpeak latency of subjects in two experimental groups was compared to that of subjects in the control group. The BERA results showed no differences among the groups ($p > 0.05$). In PTA measurements, detection thresholds at 250 Hz, 500 Hz, 1000 Hz, 2000 Hz, 4000 Hz, and 8000 Hz frequencies were measured in all three groups. No differences were observed between moderate mobile phone users (10-20 min. per day) and control subjects. However, detection thresholds in those who talked approximately 2 h per day were found to be higher than those in either moderate users or control subjects. Differences at 4000 Hz for both bone and air conduction for right ears, and 500 Hz, and 4000 Hz bone and air conduction for left ears were significant for mean hearing threshold. This study shows that a higher degree of hearing loss is associated with long-term exposure to electromagnetic (EM) field generated by cellular phones.

Oktem F, Ozguner F, Mollaoglu H, Koyu A, Uz E. Oxidative Damage in the Kidney Induced by 900-MHz-Emitted Mobile Phone: Protection by Melatonin. *Arch Med Res.* 36(4):350-355, 2005.

BACKGROUND: The mobile phones emitting 900-MHz electromagnetic radiation (EMR) may be mainly absorbed by kidneys because they are often carried in belts. Melatonin, the chief secretory product of the pineal gland, was recently found to be a potent free radical scavenger and antioxidant. The aim of this study was to examine 900-MHz mobile phone-induced oxidative stress that promotes production of reactive oxygen species (ROS) on renal tubular damage and the role of melatonin on kidney tissue against possible oxidative damage in rats. **METHODS:** The animals were randomly grouped as follows: 1) sham-operated control group and 2) study groups: i) 900-MHz EMR exposed (30 min/day for 10 days) group and ii) 900-MHz EMR exposed+melatonin (100 $\mu\text{g kg}^{-1}$) s.c. before the daily EMR exposure) treated group. Malondialdehyde (MDA), an index of lipid peroxidation, and urine N-acetyl-beta-d-glucosaminidase (NAG), a marker of renal tubular damage were used as markers of oxidative stress-induced renal impairment. Superoxide dismutase (SOD), catalase (CAT), and glutathione peroxidase (GSH-Px) activities were studied to evaluate the changes of antioxidant status. **RESULTS:** In the EMR-exposed group, while tissue MDA and urine NAG levels increased, SOD, CAT, and GSH-Px activities were reduced. Melatonin treatment reversed these effects as well. In this study, the increase in MDA levels of renal tissue and in urine NAG and also the decrease in renal SOD, CAT, GSH-Px activities demonstrated the role of oxidative mechanism induced by 900-MHz mobile phone exposure, and melatonin, via its free radical scavenging and antioxidant properties, ameliorated oxidative tissue injury in rat kidney. **CONCLUSIONS:** These results show that melatonin may exhibit a protective effect on mobile phone-induced renal impairment in rats.

Oral B, Guney M, Ozguner F, Karahan N, Mungan T, Comlekci S, Cesur G. Endometrial Apoptosis Induced by a 900-MHz Mobile Phone: Preventive Effects of Vitamins E and C. *Adv Ther.* 23(6):957-973, 2006.

Numerous reports have described the effects induced by an electromagnetic field (EMF) in various cellular systems. The purposes of this study were to examine oxidative stress that promotes production of reactive oxygen species induced by a 900-megahertz (MHz) mobile phone and the possible ameliorating effects of vitamins E and C on endometrial tissue against EMF-induced endometrial impairment and apoptosis in rats. Animals were randomly grouped as follows: (1) sham-operated control group ($n=8$), (2) 900 MHz EMF-exposed group ($n=8$; 30 min/d for 30 d), and (3) 900 MHz EMF-exposed group, treated with vitamins E and C ($n=8$; 50 mg/kg intramuscularly and 20 mg/kg body weight intraperitoneally before daily EMF exposure). Malondialdehyde (an index of lipid peroxidation) was used as a marker of oxidative stress-induced endometrial impairment; Bcl-2, Bax, caspase-3, and caspase-8 were assessed

immunohistochemically. In this study, increased malondialdehyde levels in endometrial tissue and apoptosis illustrated the role of the oxidative mechanism induced by exposure to a 900-MHz mobile phone-like device and vitamins E and C; via free radical scavenging and antioxidant properties, oxidative tissue injury and apoptosis were ameliorated in rat endometrium. In conclusion, exposure to 900-MHz radiation emitted by mobile phones may cause endometrial apoptosis and oxidative stress, but treatment with vitamins E and C can diminish these changes and may have a beneficial effect in preventing endometrial changes in rats.

Ozguner F, Aydin G, Mollaoglu H, Gokalp O, Koyu A, Cesur G. Prevention of mobile phone induced skin tissue changes by melatonin in rat: an experimental study. *Toxicol Ind Health*. 20(6-10):133-139, 2004.

Most of the mobile phones in Turkey emit 900 MHz radiation which is mainly absorbed by the skin and, to a lesser extent, muscle. The aim of this study was to investigate the effects the 900 MHz electromagnetic irradiation emitted by these devices on the induction of histopathologic changes in skin and the effect of melatonin (Mel) on any of these changes. Thirty male Wistar-Albino rats were used in the study. The experimental groups were composed of: a nontreated control group, an irradiated group (IR) without Mel and an irradiated with Mel treatment group (IR + Mel). 900 MHz radiation was applied to IR group for 10 days (30 min/day). The IR + Mel group received 10 mg/kg per day melatonin in tap water for 10 days before irradiation. At the end of the tenth day, the skin graft was excized from the thoraco-abdominal area. Histopathologic changes in skin were analyzed. In the IR group, increased thickness of stratum corneum, atrophy of epidermis, papillomatosis, basal cell proliferation, increased granular cell layer (hypergranulosis) in epidermis and capillary proliferation, impairment in collagen tissue distribution and separation of collagen bundles in dermis were all observed compared to the control group. Most of these changes, except hypergranulosis, were prevented with melatonin treatment. In conclusion, exposure to 900 MHz radiation emitted by mobile phones caused mild skin changes. Furthermore, melatonin treatment can reduce these changes and may have a beneficial effect to prevent 900 MHz mobile phone-induced rat skin changes.

Ozguner M, Koyu A, Cesur G, Ural M, Ozguner F, Gokcimen A, Delibas N. Biological and morphological effects on the reproductive organ of rats after exposure to electromagnetic field. *Saudi Med J*. 26(3):405-410, 2005.

OBJECTIVE: The biological effect of electromagnetic field (EMF) emitted from mobile phones is a current debate and still a controversial issue. Therefore, little is known on the possible adverse effects on reproduction as mobile phone bio-effects are only a very recent concern. The aim of this experimental study was to determine the biological and morphological effects of 900 MHz radiofrequency (RF) EMF on rat testes. **METHODS:** The study was performed in the Physiology and Histology Research Laboratories of Suleyman Demirel University, Faculty of Medicine, Isparta, Turkey in May 2004. Twenty adult male Sprague-Dawley rats weighing 270 - 320 gm were randomized into 2 groups of 10 animals: Group I (control group) was not exposed to EMF and Group II (EMF group) was exposed to 30 minutes per day, 5 days a week for 4 weeks to 900 MHz EMF. Testes tissues were submitted for histologic and morphologic examination. Testicular biopsy score count and the percentage of interstitial tissue to the entire testicular tissue were registered. Serum testosterone, plasma luteinizing hormone (LH) and follicle stimulating hormone (FSH) levels were assayed biochemically. **RESULTS:** The weight of testes, testicular biopsy score count and the percentage of interstitial tissue to the entire testicular tissue were not significantly different in EMF group compared to the control group. However, the diameter of the seminiferous tubules and the mean height of the germinal epithelium were significantly decreased in EMF group ($p < 0.05$). There was a significant decrease in serum total testosterone level in EMF group ($p < 0.05$). Therefore, there was an insignificant decrease in plasma LH and FSH levels in EMF group compared to the control group ($p > 0.05$). **CONCLUSION:** The biological and morphological effects resulting from 900 MHz RF EMF exposure lends no support to suggestions of adverse effect on spermatogenesis, and on germinal epithelium. Therefore, testicular morphologic alterations may possibly be due to hormonal changes.

Ozguner F, Oktem F, Ayata A, Koyu A, Yilmaz HR. A novel antioxidant agent caffeic acid phenethyl ester prevents long-term mobile phone exposure-induced renal impairment in rat. Prognostic value of malondialdehyde, N-acetyl-beta-D-glucosaminidase and nitric oxide determination. *Mol Cell Biochem*. 277(1-2):73-80, 2005a.

Caffeic acid phenethyl ester (CAPE), a flavonoid like compound, is one of the major components of honeybee propolis. It has been used in folk medicine for many years in Middle East countries. It was found to be a potent free radical scavenger and antioxidant recently. The aim of this study was to examine long-term applied 900 MHz emitting mobile phone-induced oxidative stress that promotes production of reactive oxygen species (ROS) and, was to investigate the role of CAPE on kidney tissue against the possible electromagnetic radiation (EMR)-induced renal impairment in rats. In particular, the ROS such as superoxide and nitric oxide (NO) may contribute to the pathophysiology of EMR-induced renal impairment. Malondialdehyde (MDA, an index of lipid peroxidation) levels, urinary N-acetyl-beta-D: -glucosaminidase (NAG, a marker of renal tubular injury) and nitric oxide (NO, an oxidant product) levels were used as markers of oxidative stress-induced renal impairment and the success of CAPE treatment. The activities of superoxide dismutase (SOD), catalase (CAT), and glutathione peroxidase (GSH-Px) in renal tissue were determined to evaluate the changes of antioxidant status. The rats used in the study were randomly grouped (10 each) as follows: i) Control group (without stress and EMR), ii) Sham-operated rats stayed without exposure to EMR (exposure device off), iii) Rats exposed to 900 MHz EMR (EMR group), and iv) A 900 MHz EMR exposed + CAPE treated group (EMR + CAPE group). In the EMR exposed group, while tissue MDA, NO levels and urinary NAG levels increased ($p < 0.0001$), the activities of SOD, CAT, and GSH-Px in renal tissue were reduced ($p < 0.001$). CAPE treatment reversed these effects as well ($p < 0.0001$, $p < 0.001$ respectively). In conclusion, the increase in NO and MDA levels of renal tissue, and in urinary NAG with the decrease in renal SOD, CAT, GSH-Px activities demonstrate the role of oxidative mechanisms in 900 MHz mobile phone-induced renal tissue damage, and CAPE, via its free radical scavenging and antioxidant properties, ameliorates oxidative renal damage. These results strongly suggest that CAPE exhibits a protective effect on mobile phone-induced and free radical mediated oxidative renal impairment in rats.

Ozguner F, Oktem F, Armagan A, Yilmaz R, Koyu A, Demirel R, Vural H, Uz E. Comparative analysis of the protective effects of melatonin and caffeic acid phenethyl ester (CAPE) on mobile phone-induced renal impairment in rat. *Mol Cell Biochem.* 276(1-2):31-37, 2005b.

Melatonin and caffeic acid phenethyl ester (CAPE), a component of honeybee propolis, were recently found to be potent free radical scavengers and antioxidants. There are a number of reports on the effects induced by electromagnetic radiation (EMR) in various cellular systems. Mechanisms of adverse effects of EMR indicate that reactive oxygen species may play a role in the biological effects of this radiation. The present study was carried out to compare the protective effects of melatonin and CAPE against 900 MHz EMR emitted mobile phone-induced renal tubular injury. Melatonin was administered whereas CAPE was given for 10 days before the exposure. Urinary N-acetyl-beta-D-glucosaminidase (NAG, a marker of renal tubular injury) and malondialdehyde (MDA, an index of lipid peroxidation), were used as markers of oxidative stress-induced renal impairment in rats exposed to EMR. Superoxide dismutase (SOD), catalase (CAT), and glutathione peroxidase (GSH-Px) activities were studied to evaluate the changes of antioxidant status in renal tissue. Urinary NAG and renal MDA were increased in EMR exposed rats while both melatonin and CAPE caused a significant reduction in the levels of these parameters. Likewise, renal SOD and GSH-Px activities were decreased in EMR exposed animals while melatonin caused a significant increase in the activities of these antioxidant enzymes but CAPE did not. Melatonin caused a significant decrease in urinary NAG activity and MDA levels which were increased because of EMR exposure. CAPE also reduced elevated MDA levels in EMR exposed renal tissue, but the effect of melatonin was more potent than that of CAPE. Furthermore, treatment of EMR exposed rats with melatonin increased activities of SOD and GSH-Px to higher levels than those of control rats. In conclusion, melatonin and CAPE prevent renal tubular injury by reducing oxidative stress and protect the kidney from oxidative damage induced by 900 MHz mobile phone. Nevertheless, melatonin seems to be a more potent antioxidant compared with CAPE in kidney.

Ozguner F, Altinbas A, Ozaydin M, Dogan A, Vural H, Kisioglu AN, Cesur G, Yildirim NG. Mobile phone-induced myocardial oxidative stress: protection by a novel antioxidant agent caffeic acid phenethyl ester. *Toxicol Ind Health.* 21(9):223-230, 2005c.

Electromagnetic radiation (EMR) or radiofrequency fields of cellular mobile phones may affect biological systems by increasing free radicals, which appear mainly to enhance lipid peroxidation, and by changing the antioxidant defense systems of human tissues, thus leading to oxidative stress. Mobile phones are used in close proximity to the heart,

therefore 900 MHz EMR emitting mobile phones may be absorbed by the heart. Caffeic acid phenethyl ester (CAPE), one of the major components of honeybee propolis, was recently found to be a potent free radical scavenger and antioxidant, and is used in folk medicine. The aim of this study was to examine 900 MHz mobile phone-induced oxidative stress that promotes production of reactive oxygen species (ROS) and the role of CAPE on myocardial tissue against possible oxidative damage in rats. Thirty rats were used in the study. Animals were randomly grouped as follows: sham-operated control group (N: 10) and experimental groups: (a) group II: 900 MHz EMR exposed group (N: 10); and (b) group III: 900 MHz EMR exposed+CAPE-treated group (N: 10). A 900 MHz EMR radiation was applied to groups II and III 30 min/day, for 10 days using an experimental exposure device. Malondialdehyde (MDA, an index of lipid peroxidation), and nitric oxide (NO, a marker of oxidative stress) were used as markers of oxidative stress-induced heart impairment. Superoxide dismutase (SOD), catalase (CAT), and glutathione peroxidase (GSH-Px) activities were studied to evaluate the changes of antioxidant status. In the EMR exposed group, while tissue MDA and NO levels increased, SOD, CAT and GSH-Px activities were reduced. CAPE treatment in group III reversed these effects. In this study, the increased levels of MDA and NO and the decreased levels of myocardial SOD, CAT and GSH-Px activities demonstrate the role of oxidative mechanisms in 900 MHz mobile phone-induced heart tissue damage, and CAPE, via its free radical scavenging and antioxidant properties, ameliorates oxidative heart injury. These results show that CAPE exhibits a protective effect on mobile phone-induced and free radical mediated oxidative heart impairment in rats.

Ozguner F, Bardak Y, Comlekci S. Protective effects of melatonin and caffeic acid phenethyl ester against retinal oxidative stress in long-term use of mobile phone: A comparative study. *Mol Cell Biochem.* 282(1-2):83-88, 2006.

There are numerous reports on the effects of electromagnetic radiation (EMR) in various cellular systems. Melatonin and caffeic acid phenethyl ester (CAPE), a component of honeybee propolis, were recently found to be potent free radical scavengers and antioxidants. Mechanisms of adverse effects of EMR indicate that reactive oxygen species may play a role in the biological effects of this radiation. The present study was carried out to compare the efficacy of the protective effects of melatonin and CAPE against retinal oxidative stress due to long-term exposure to 900 MHz EMR emitting mobile phones. Melatonin and CAPE were administered daily for 60 days to the rats prior to their EMR exposure during our study. Nitric oxide (NO, an oxidant product) levels and malondialdehyde (MDA, an index of lipid peroxidation), were used as markers of retinal oxidative stress in rats following to use of EMR. Superoxide dismutase (SOD), catalase (CAT), and glutathione peroxidase (GSH-Px) activities were studied to evaluate the changes of antioxidant status in retinal tissue. Retinal levels of NO and MDA increased in EMR exposed rats while both melatonin and CAPE caused a significant reduction in the levels of NO and MDA. Likewise, retinal SOD, GSH-Px and CAT activities decreased in EMR exposed animals while melatonin and CAPE caused a significant increase in the activities of these antioxidant enzymes. Treatment of EMR exposed rats with melatonin or CAPE increased the activities of SOD, GSH-Px and CAT to higher levels than those of control rats. In conclusion, melatonin and CAPE reduce retinal oxidative stress after long-term exposure to 900 MHz emitting mobile phone. Nevertheless, there was no statistically significant difference between the efficacies of these two antioxidants against to EMR induced oxidative stress in rat retina. The difference was in only GSH-Px activity in rat retina. Melatonin stimulated the retinal GSH-Px activity more efficiently than CAPE did.

Ozturan O, Erdem T, Miman MC, Kalcioğlu MT, Oncel S. Effects of the electromagnetic field of mobile telephones on hearing. *Acta Otolaryngol.* 122(3):289-293, 2002.

The widespread use of mobile telephones has given rise to concern about the potential influences of electromagnetic fields (EMFs) on human health. Anatomically, the ear is in close proximity to the mobile telephone during use. Hearing loss due to mobile telephone use has not been described in the medical literature; however, if there is a subtle cochlear involvement, it might be detected by means of changes in evoked otoacoustic emissions (OAEs). Thirty volunteers with normal hearing were exposed to mobile telephone EMFs for 10 min and evoked OAEs were measured before and after exposure. No measurable change in evoked OAEs was detected and none of the subjects reported a deterioration in hearing level. To the best of our knowledge, this is the first study on the effects of EMFs emitted by mobile telephones on hearing. It was concluded that a 10-min exposure to the EMF emitted from a mobile telephone had no effect on hearing, at least at outer ear, middle ear and cochlear levels.

Pacini S, Ruggiero M, Sardi I, Aterini S, Gulisano F, Gulisano M. Exposure to global system for mobile communication (GSM) cellular phone radiofrequency alters gene expression, proliferation, and morphology of

human skin fibroblasts. *Oncol Res* 13(1):19-24, 2002.

Human skin fibroblasts were exposed to global system for mobile communication (GSM) cellular phone radiofrequency for 1 h. GSM exposure induced alterations in cell morphology and increased the expression of mitogenic signal transduction genes (e.g., MAP kinase kinase 3, G2/mitotic-specific cyclin G1), cell growth inhibitors (e.g., transforming growth factor-beta), and genes controlling apoptosis (e.g., bax). A significant increase in DNA synthesis and intracellular mitogenic second messenger formation matched the high expression of MAP kinase family genes. These findings show that these electromagnetic fields have significant biological effects on human skin fibroblasts.

Paglialonga A, Tognola G, Parazzini M, Lutman ME, Bell SL, Thuroczy G, Ravazzani P. Effects of mobile phone exposure on time frequency fine structure of transiently evoked otoacoustic emissions. *J Acoust Soc Am.* 122(4):2174-2182, 2007.

Mobile phones have become very commonly used worldwide within a short period of time. To date there is only limited knowledge about interaction between electromagnetic fields (EMFs) emitted by mobile phones and the auditory function. Moreover, there is widespread concern that there may be potential for harm. The aim of this study was to assess potential subtle changes in cochlear function by measuring the temporal and spectral fine structure of transiently evoked otoacoustic emissions (TEOAE) in normal hearing subjects after exposure to EMFs emitted by Global System for Mobile Communication (GSM) mobile phones. TEOAEs were recorded in 27 healthy young adults before and after 10 min of real or sham exposure in a double-blind design. TEOAE data were analyzed both globally (broadband analysis) and using the Wavelet Transform (analysis of the time-frequency fine structure). The broadband analysis revealed no significant effect on TEOAEs related to exposure, confirming results of previous studies; in addition, no significant change was detected in the analysis of the elementary wavelet components, suggesting that the temporal and spectral fine structure of TEOAEs is not affected by 10 min exposure to low-intensity EMFs emitted by GSM mobile phones.

Palumbo R, Brescia F, Capasso D, Sannino A, Sarti M, Capri M, Grassilli E, Scarfi MR. Exposure to 900 MHz Radiofrequency Radiation Induces Caspase 3 Activation in Proliferating Human Lymphocytes. *Radiat Res.* 170(3):327-334, 2008.

In this study, the induction of apoptosis after exposure to 900 MHz radiofrequency radiation (GSM signal) was investigated by assessing caspase 3 activation in exponentially growing Jurkat cells and in quiescent and proliferating human peripheral blood lymphocytes (PBLs). The exposure was carried out at an average specific absorption rate of 1.35 W/kg in a dual wire patch cell exposure system where the temperature of cell cultures was accurately controlled. After 1 h exposure to the radiofrequency field, a slight but statistically significant increase in caspase 3 activity, measured 6 h after exposure, was observed in Jurkat cells (32.4%) and in proliferating human PBLs (22%). In contrast, no effect was detected in quiescent human PBLs. In the same experimental conditions, apoptosis was also evaluated in Jurkat cells by Western blot analysis and in both cell types by flow cytometry. To evaluate late effects due to caspase 3 activity, flow cytometry was also employed to assess apoptosis and viability 24 h after radiofrequency-radiation exposure in both cell types. Neither the former nor the latter was affected. Since in recent years it has been reported that caspases are also involved in processes other than apoptosis, additional cell cycle studies were carried out on proliferating T cells exposed to radiofrequency radiation; however, we found no differences between sham-exposed and exposed cultures. Further studies are warranted to investigate the biological significance of our findings of a dose-response increase in caspase 3 activity after exposure to radiofrequency radiation.

Panagopoulos DJ, Karabarbounis A, Margaritis LH. Effect of GSM 900-MHz mobile phone radiation on the reproductive capacity of *Drosophila melanogaster*. *Electromag. Biol. Med.* 23:29-43, 2004.

Pulsed radio frequency, (RF), electromagnetic radiation from common GSM mobile phones, (Global System for Mobile Telecommunications) with a carrier frequency at 900 MHz, “modulated” by human voice, (speaking emission) decreases the reproductive capacity of the insect *Drosophila melanogaster* by 50%–60%, whereas the corresponding “nonmodulated” field (nonspeaking emission) decreases the reproductive capacity by 15%–20%. The insects were exposed to the near field of the mobile phone antenna for 6 min per day during the first 2–5 days of their adult lives. The GSM field is found to affect both females and males. Our results suggest that this field-radiation decreases the rate of cellular processes during gonad development in insects.

Panagopoulos DJ, Chavdoula ED, Nezis IP, Margaritis LH Cell death induced by GSM 900-MHz and DCS 1800-MHz mobile telephony radiation. *Mutat Res.* 2006 Oct 10; [Epub ahead of print]

In the present study, the TUNEL (Terminal deoxynucleotide transferase dUTP Nick End Labeling) assay - a well known technique widely used for detecting fragmented DNA in various types of cells - was used to detect cell death (DNA fragmentation) in a biological model, the early and mid stages of oogenesis of the insect *Drosophila melanogaster*. The flies were exposed in vivo to either GSM 900-MHz (Global System for Mobile telecommunications) or DCS 1800-MHz (Digital Cellular System) radiation from a common digital mobile phone, for few minutes per day during the first 6 days of their adult life. The exposure conditions were similar to those to which a mobile phone user is exposed, and were determined according to previous studies of ours [D.J. Panagopoulos, A. Karabarounis, L.H. Margaritis, Effect of GSM 900-MHz mobile phone radiation on the reproductive capacity of *D. melanogaster*, *Electromagn. Biol. Med.* 23 (1) (2004) 29-43; D.J. Panagopoulos, N. Messini, A. Karabarounis, A.L. Philippetis, L.H. Margaritis, Radio frequency electromagnetic radiation within "safety levels" alters the physiological function of insects, in: P. Kostarakis, P. Stavroulakis (Eds.), *Proceedings of the Millennium International Workshop on Biological Effects of Electromagnetic Fields*, Heraklion, Crete, Greece, October 17-20, 2000, pp. 169-175, ISBN: 960-86733-0-5; D.J. Panagopoulos, L.H. Margaritis, Effects of electromagnetic fields on the reproductive capacity of *D. melanogaster*, in: P. Stavroulakis (Ed.), *Biological Effects of Electromagnetic Fields*, Springer, 2003, pp. 545-578], which had shown a large decrease in the oviposition of the same insect caused by GSM radiation. Our present results suggest that the decrease in oviposition previously reported, is due to degeneration of large numbers of egg chambers after DNA fragmentation of their constituent cells, induced by both types of mobile telephony radiation. Induced cell death is recorded for the first time, in all types of cells constituting an egg chamber (follicle cells, nurse cells and the oocyte) and in all stages of the early and mid-oogenesis, from germarium to stage 10, during which programmed cell death does not physiologically occur. Germarium and stages 7-8 were found to be the most sensitive developmental stages also in response to electromagnetic stress induced by the GSM and DCS fields and, moreover, germarium was found to be even more sensitive than stages 7-8.

Panagopoulos DJ, Chavdoula ED, Karabarounis A, Margaritis LH. Comparison of bioactivity between GSM 900 MHz and DCS 1800 MHz mobile telephony radiation. *Electromagn Biol Med.* 26(1):33-44, 2007.

An increasing number of studies find that pulsed Radio Frequency (RF), electromagnetic radiation of both systems of digital mobile telephony, established and commonly used in Europe during the last years, GSM 900 MHz (Global System for Mobile telecommunications) and DCS 1800 MHz (Digital Cellular System), exert intense biological action on different organisms and cells (Hardell et al., 2006; Hyland, 2000; Kundi, 2004; Panagopoulos et al., 2004, 2007). The two types of cellular telephony radiation use different carrier frequencies and give different frequency spectra, but they usually also differ in intensity, as GSM 900 MHz antennas operate at about double the power output than the corresponding DCS 1800 MHz ones. In our present experiments, we used a model biological system, the reproductive capacity of *Drosophila melanogaster*, to compare the biological activity between the two systems of cellular mobile telephony radiation. Both types of radiation were found to decrease significantly and non thermally the insect's reproductive capacity, but GSM 900 MHz seems to be even more bioactive than DCS 1800 MHz. The difference seems to be dependent mostly on field intensity and less on carrier frequency.

Papageorgiou CC, Nanou ED, Tsiafakis VG, Capsalis CN, Rabavilas AD. Gender related differences on the EEG during a simulated mobile phone signal. *Neuroreport.* 15(16):2557-2560, 2004.

The present study investigated the gender-related influence of electromagnetic fields (EMF), similar to that emitted by mobile phones, on brain activity. Ten women and nine men performed a short memory task (Wechsler test), both without (baseline) and with exposure to a 900 MHz signal. The EEG energy of the total waveform and the alpha, beta, delta and theta; rhythms were calculated from the recordings of 15 scalp electrodes. Baseline EEG energy of males was greater than that of females, while exposure to EMF decreased EEG energy of males and increased that of females. Memory performance was invariant to EMF exposure and gender influences. These findings indicate that EMF may exert a gender-related influence on brain activity.

Papageorgiou CC, Nanou ED, Tsiafakis VG, Kapareliotis E, Kontoangelos KA, Capsalis CN, Rabavilas AD, Soldatos CR. Acute mobile phone effects on pre-attentive operation. Neurosci Lett. 2006 Jan 4; [Epub ahead of print]

There is a debate whether electromagnetic field (EMF) emitted by mobile phones (MP) have an effect on cognitive functions. Since the auditory P50 component of event-related potentials (ERPs) reflects pre-attentive processing and working memory (WM) operation, the present study was designed to investigate whether the exposure to MP-EMF affects the patterns of the P50 component of ERPs elicited during a WM test. The P50 elicited during a WM task and evoked by two warning stimuli low and high frequency (500 and 3000Hz) has been assessed in 19 normal subjects (10 women and 9 men) both without and with exposure to a 900MHz signal, emitted by a dipole antenna placed near the subjects. Results showed that the presence of MP-EMFs induced statistically significant increase in the amplitude of P50 evoked by the low frequency stimuli, at Fp1 and O1 electrode leads as compared to themselves without MP-EMF exposure. In contrast the exposure to MP-EMFs revealed statistically significant decrease of the amplitude of P50 evoked by the high frequency stimuli, at Fp1 electrode lead as compared to themselves without MP-EMF exposure. These findings provide evidence that the MP-EMF emitted by mobile phone affect pre-attentive information processing as it is reflected in P50 evoked potential. The basis of such an effect is unclear, although several possibilities exist and call for potential directions of future research.

Parazzini M, Bell S, Thuroczy G, Molnar F, Tognola G, Lutman ME, Ravazzani P. Influence on the mechanisms of generation of distortion product otoacoustic emissions of mobile phone exposure. Hear Res. 2005 Jul 26; [Epub ahead of print]

Mobile phones have become very commonly used throughout the world within a short period of time. Although there is no clear evidence to show harmful physiological effects of electromagnetic fields (EMF) at the levels used by mobile phones, there is widespread public concern that there may be potential for harm. Because mobile phones are usually held close to the ear, it is appropriate to study effects on hearing. In this study, the outer hair cell function of 15 subjects was assessed by DPOAE recording before and after a controlled EMF exposure. To increase the sensitivity of DPOAE recording to identify even small changes in hearing function, an inverse fast Fourier transform (IFFT) analysis and time-domain windowing was applied to separate the two generation mechanisms of DPOAE, the so-called place-fixed and wave-fixed mechanisms, in order to verify if EMF can affects the two DPOAE emission mechanisms. Statistical analysis of the data showed that 10min of EMF exposure at the maximum power (2W at 900MHz or 1W at 1800MHz) does not induce any changes in either DPOAE generation mechanism.

Parazzini M, Ravazzani P, Tognola G, Thuroczy G, Molnar FB, Sacchetti A, Ardesi G, Mainardi LT. Electromagnetic fields produced by GSM cellular phones and heart rate variability. Bioelectromagnetics. 2006 Sep 26; [Epub ahead of print]

In this study, 26 healthy young volunteers were submitted to 900 MHz (2 W) GSM cellular phone exposure and to sham exposure in separate sessions. The study was designed to assess cardiac regulatory mechanism in different autonomic nervous system (ANS) states during exposure to low-intensity EMF. Rest-to-stand protocol was applied to evaluate ANS in quiet condition (rest, vagal prevalence) and after a sympathetic activation (stand). The procedure is conducted twice in a double-blind design: once with a genuine EMF exposure and once with a sham exposure (at least 24 h apart). During each session three-leads electrocardiograms were recorded and RR series extracted off-line. Time domain and frequency domain HRV parameters were calculated in every phase of the protocol and during different exposures. The analysis of the data show there was no statistically significant effect due to EMF exposure both on main (i.e., RR mean) and most of the other HRV parameters. A weak interaction between some HRV parameters (i.e., SDNN, TINN, and triangular index in time domain and LF power in frequency domain analysis) and RF exposure was observed and this effect seems to be gathered around the sympathetic response to stand.

Parazzini M, Brazzale AR, Paglialonga A, Tognola G, Collet L, Moulin A, Lutman ME, Bell SL, Thomas NA, Uloziene I, Uloza V, Thuroczy G, Tavartkiladze G, Tsalighopoulos M, Kyriafinis G, Ravazzani P. Effects of GSM Cellular Phones on Human Hearing: The European Project "GUARD". Radiat Res. 168(5):608-613, 2007.

.The European multicenter project named GUARD involved nine centers and aimed to assess potential changes in auditory function as a consequence of exposure to low-intensity electromagnetic fields (EMFs) produced by GSM cellular

phones. Participants were healthy young adults without any evidence of hearing or ear disorders. Auditory function was assessed immediately before and after exposure to EMFs, and only the exposed ear was tested. The procedure was conducted twice in a double blinded design, once with a genuine EMF exposure and once with a sham exposure (at least 24 h apart). Tests for assessment of auditory function were hearing threshold level (HTL), transient otoacoustic emissions (TEOAE), distortion product otoacoustic emissions (DPOAE), and auditory brainstem response (ABR). The exposure consisted of speech at a typical conversational level delivered via an earphone to one ear, plus genuine or sham EMF exposure. The EMF exposure used the output of a software-controlled consumer cellular phone at full power for 10 min. A system of phone positioning that allowed participants to freely move their heads without affecting exposure was used. Analysis of the data showed there were no effects of exposure to GSM mobile phone signals on the main measures of the status of the auditory system.

Paredi P, Kharitonov SA, Hanazawa T, Barnes PJ, Local vasodilator response to mobile phones. *Laryngoscope* 111(1):159-162, 2001.

OBJECTIVES: The use of mobile phones with the resulting generation of potentially harmful electromagnetic fields (EMF) is the focus of public interest. Heat generation and the activation of the inducible form of nitric oxide (NO) synthase may be possible causes of the biological effects of EMF exposure. We investigated if a mobile telephone conversation can modify skin temperature, NO, and nasal resistance. **METHODS:** We studied the effect of an EMF (900 MHz) generated by a commercially available cellular phone during a 30-minute telephone conversation on skin temperature, nasal NO measured by chemiluminescence, and nasal minimal cross-sectional area (MCA) measured by rhinometry. Eleven normal subjects (mean age \pm standard error of mean [SEM], 32 \pm 5 y; 10 male) were studied. **RESULTS:** There was a similar and significant increase in skin temperature of the nostril and occipital area on the same side as the telephone (maximal increase 2.3 \pm 0.2 degrees C at 6 min) as well as a tendency for higher nasal NO levels (maximal increase 12.9 \pm 4.9% at 10 min), whereas the MCA was significantly reduced (maximal decrease -27 \pm 6% at 15 min). Such changes were not recorded when an earpiece was used to avoid the direct exposure to the electromagnetic field. There were no changes in the skin temperature and nasal NO measured on the opposite side to the mobile phone, whereas the MCA was significantly increased (38 \pm 10%). **CONCLUSIONS:** Exposure to EMF produced by a mobile phone produces biological effects that can be easily measured. Microwaves may increase skin temperature and therefore cause vasodilation and reduce MCA. Further studies are needed to study the long-term effects of mobile phone use and the relation among NO production, vasodilation, and temperature.

Pau HW, Sievert U, Eggert S, Wild W. Can electromagnetic fields emitted by mobile phones stimulate the vestibular organ? *Otolaryngol Head Neck Surg.* 132(1):43-49, 2005.

Objectives Pulsating electromagnetic (EM) radiation emitted by mobile phones is often incriminated for causing tissue alterations by caloric effects. In particular, the eye and the ear were regarded as possible "hot spots," with heating up to 1 degrees C, in which EM radiation might have negative effects. If so, these temperature increments should be large enough to cause vestibular excitation. In this study, we attempted to verify this theory by clinical testing and in vitro experiments. **Methods and measures** In our laboratory, a simulated GSM signal (889.6 MHz/2.2 W) was applied to 1 ear at a time, while video nystagmography was performed. The experimental setup was similar to that used for caloric (hot and cold water) testing of the peripheral vestibular organ. Data were evaluated by a computer system. There were 13 volunteers (26 ears) included in our study. In an additional experiment, temperatures of human temporal bones were measured by thermography, while a continuous or pulsating EM field was applied. **Results** In no volunteer could EM radiation-induced nystagmus be recorded. This corresponds well to our findings that in the human temporal bone very weak caloric effects could only be found in the tissue layers next to the radiation source (antenna of the mobile phone), whereas deeper regions (horizontal semicircular canal) seemed unaffected (at least less than 0.1 degrees C). **Clinical significance** These results do not support the theory that mobile phone-induced EM radiation may cause caloric negative effects in the human ear.

Pavicic I, Trosic I, Sarolic A. Comparison of 864 MHz and 935 MHz microwave radiation effects on cell culture. *Arh Hig Rada Toksikol.* 57(2):149-154, 2006.

The objective of this study was to compare the effects of 864 MHz and 935 MHz radiofrequency/microwave radiation on

the ability of V79 cells to proliferate, form colonies and on their viability. For one, two and three hours, the cells were exposed to the 864 MHz field in a transversal electromagnetic mode cell (TEM) connected with amplifier and to the 935 MHz field in a gigahertz transversal electromagnetic mode cell (GTEM) equipped with a signal generator. The average specific absorption rate (SAR) was 0.08 W kg⁻¹ for the 864 MHz field and 0.12 W kg⁻¹ for the 935 MHz field. In comparison to the control cell samples, the growth curve of the 864 MHz irradiated cells showed a significant decrease after two-hour and three-hour exposure on the Day 3 after exposure. Likewise, cells exposed to 935 MHz microwaves for three hours showed a significant growth on Day 3 after exposure. The colony-forming ability and viability of cells exposed to 864 MHz and 935 MHz microwaves did not significantly differ from the matched controls. The applied RF/MW fields showed a similar effect on cell culture growth, colony-forming ability and viability of V79 cells.

Penafiel LM, Litovitz T, Krause D, Desta A, Mullins JM, Role of modulation on the effect of microwaves on ornithine decarboxylase activity in L929 cells. *Bioelectromagnetics* 18(2):132-141, 1997.

The effect of 835 MHz microwaves on the activity of ornithine decarboxylase (ODC) in L929 murine cell was investigated at an SAR of approximately 2.5 W/kg. The results depended upon the type of modulation employed. AM frequencies of 16 Hz and 60 Hz produced a transient increase in ODC activity that reached a peak at 8 h of exposure and returned to control levels after 24 h of exposure. In this case, ODC was increased by a maximum of 90% relative to control levels. A 40% increase in ODC activity was also observed after 8 h of exposure with a typical signal from a TDMA digital cellular telephone operating in the middle of its transmission frequency range (approximately 840 MHz). This signal was burst modulated at 50 Hz, with approximately 30% duty cycle. By contrast, 8 h exposure with 835 MHz microwaves amplitude modulated with speech produced no significant change in ODC activity. Further investigations, with 8 h of exposure to AM microwaves, as a function of modulation frequency, revealed that the response is frequency dependent, decreasing sharply at 6 Hz and 600 Hz. Exposure with 835 MHz microwaves, frequency modulated with a 60 Hz sinusoid, yielded no significant enhancement in ODC activity for exposure times ranging between 2 and 24 h. Similarly, exposure with a typical signal from an AMPS analog cellular telephone, which uses a form of frequency modulation, produced no significant enhancement in ODC activity. Exposure with 835 MHz continuous wave microwaves produced no effects for exposure times between 2 and 24 h, except for a small but statistically significant enhancement in ODC activity after 6 h of exposure. Comparison of these results suggests that effects are much more robust when the modulation causes low-frequency periodic changes in the amplitude of the microwave carrier.

Perentos N, Croft RJ, McKenzie RJ, Cvetkovic D, Cosic I. Comparison of the effects of continuous and pulsed mobile phone like RF exposure on the human EEG. *Australas Phys Eng Sci Med.* 30(4):274-280, 2007.

It is not clear yet whether Global System for Mobiles (GSM) mobile phone radiation has the ability to interfere with normal resting brain function. There have been reports that GSM exposure increases alpha band power, and does so only when the signal is modulated at low frequencies (Huber, R., Treyer, V., Borbely, A. A., Schuderer, J., Gottselig, J. M., Landolt, H.P., Werth, E., Berthold, T., Kuster, N., Buck, A and Achermann, P. Electromagnetic fields, such as those from mobile phones, alter regional cerebral blood flow and sleep and waking EEG. *J Sleep Res* 11, 289-295, 2002.) However, as that research employed exposure distributions that are not typical of normal GSM handset usage (deep brain areas were overexposed), it remains to be determined whether a similar result patterning would arise from a more representative exposure. In this fully counterbalanced cross-over design, we recruited 12 participants and tried to replicate the modulation linked post exposure alpha band power increase described above, but with an exposure source (dipole antenna) more closely resembling that of a real GSM handset. Exposures lasted for 15 minutes. No changes to alpha power were found for either modulated or unmodulated radiofrequency fields, and thus we failed to replicate the above results. Possible reasons for this failure to replicate are discussed, with the main reason argued to be the lower and more representative exposure distribution employed in the present study. In addition we investigated the possible GSM exposure related effects on the non-linear features of the resting electroencephalogram using the Approximate Entropy (ApEn) method of analysis. Again, no effect was demonstrated for either modulated or unmodulated radiofrequency exposures.

Perentos N, Croft RJ, McKenzie RJ, Cvetkovic D, Cosic I. The effect of GSM-like ELF radiation on the alpha band of the human resting EEG. *Conf Proc IEEE Eng Med Biol Soc.* 2008;1:5680-5683.

Mobile phone handsets such as those operating in the GSM network emit extremely low frequency electromagnetic fields ranging from DC to at least 40 kHz. As a subpart of an extended protocol, the influence of these fields on the human

resting EEG has been investigated in a fully counter balanced, double blind, cross-over design study that recruited 72 healthy volunteers. A decrease in the alpha frequency band was observed during the 20 minutes of ELF exposure in the exposed hemisphere only. This result suggests that ELF fields as emitted from GSM handsets during the DTX mode may have an effect on the resting alpha band of the human EEG.

Persson BRR, Salford LG, Brun A, Blood-brain barrier permeability in rats exposed to electromagnetic fields used in wireless communication. *Wireless Network* 3:455-461, 1997.

Biological effects of radio frequency electromagnetic fields (EMF) on the blood-brain barrier (BBB) have been studied in Fischer 344 rats of both sexes. The rats were not anesthetised during the exposure. The brains were perfused with saline for 3-4 minutes, and thereafter perfusion fixed with 4% formaldehyde for 5-6 minutes. Whole coronal sections of the brains were dehydrated and embedded in paraffin and sectioned at 5 micrometers. Albumin and fibinogen were demonstrated immunochemically and classified as normal versus pathological leakage. In the present investigation we exposed male and female Fischer 344 rats in a Transverse Electromagnetic Transmission line camber to microwaves of 915 MHz as continuous wave (CW) and pulse-modulated with different pulse power and at various time intervals. The CW-pulse power varied from 0.001 W to 10 W and the exposure time from 2 min to 960 min. In each experiment we exposed 4-6 rats with 2-4 controls randomly placed in excited and non-excited TEM cells, respectively. We have in total investigated 630 exposed rats at various modulation frequencies and 372 controls. The frequency of pathological rats is significantly increased ($P < 0.0001$) from 62/372 (ratio 0.17 ± 0.02) for control rats to 244/630 (ratio: 0.39 ± 0.043) in all exposed rats. Grouping the exposed animals according to the level or specific absorption energy (J/kg) give significant difference in all levels above 1.5 J/kg. The exposure was 915 MHz microwaves either pulse modulated (PW) at 217 Hz with 0.57 ms pulse width, at 50 Hz with 6.6 ms pulse width or continuous wave (CW). The frequency of pathological rats (0.17) among controls in the various groups is not significantly different. The frequency of pathological rats was 170/480 (0.35 ± 0.03) among rats exposed to pulse modulated (PW) and 74/149 (0.50 ± 0.07) among rats exposed to continuous wave exposure (CW). These results are both highly significantly different to their corresponding controls ($p < 0.0001$) and the frequency of pathological rats after exposure to pulsed radiation (PW) is significantly less ($p < 0.002$) than after exposure to continuous wave radiation (CW).

Phillips, J.L., Ivaschuk, O., Ishida-Jones, T., Jones, R.A., Campbell-Beachler, M. and Haggren, W. DNA damage in Molt-4 T- lymphoblastoid cells exposed to cellular telephone radiofrequency fields in vitro. *Bioelectrochem. Bioenerg.* 45:103-110, 1998.

Molt-4 T-lymphoblastoid cells have been exposed to pulsed signals at cellular telephone frequencies of 813.5625 MHz (iDEN signal) and 836.55 MHz (TDMA signal). These studies were performed at low SAR (average = 2.4 and 24 microwatt/g for iDEN and 2.6 and 26 microwatt/g for TDMA) in studies designed to look for athermal RF effects. The alkaline comet, or single cell gel electrophoresis, assay was employed to measure DNA single-strand breaks in cell cultures exposed to the radiofrequency (RF) signal as compared to concurrent sham-exposed cultures. Tail moment and comet extent were calculated as indicators of DNA damage. Statistical differences in the distribution of values for tail moment and comet extent between exposed and control cell cultures were evaluated with the Kolmogorov-Smirnoff distribution test. Data points for all experiments of each exposure condition were pooled and analyzed as single groups. It was found that: 1) exposure of cells to the iDEN signal at an SAR of 2.4 microwatt/g for 2 h or 21 h significantly decreased DNA damage; 2) exposure of cells to the TDMA signal at an SAR of 2.6 microwatt/g for 2 h and 21 h significantly decreased DNA damage; 3) exposure of cells to the iDEN signal at an SAR of 24 microwatt/g for 2 h and 21 h significantly increased DNA damage; 4) exposure of cells to the TDMA signal at an SAR of 26 microwatt/g for 2 h significantly decreased DNA damage. The data indicate a need to study the effects of exposure to RF signals on direct DNA damage and on the rate at which DNA damage is repaired.

Philippova TM, Novoselov VI, Alekseev SI, Influence of microwaves on different types of receptors and the role of peroxidation of lipids on receptor-protein shedding. *Bioelectromagnetics* 15(3):183-192, 1994.

The effects of a continuous wave or pulse-modulated, 900 MHz microwave field were studied by in vitro assays of rat chemoreceptors. The pulsed field was modulated as rectangular waves at rates of 1, 6, 16, 32, 75, or 100 pps. The pulse-period to pulse-duration ratio was 5 in all cases, and specific absorption rates (SARs) ranged from 0.5 to 18 W/kg.

Binding of ligands to cell membranes was differentially affected by exposure to microwaves. For example, binding of H3-glutamic acid to hippocampal cells was not altered by a 15 min exposure to a continuous wave field at 1 W/kg, but binding of H3-dihydroalprenolol to liver-cell membranes of neonates underwent a fivefold decrease under the same field conditions. This effect was not dependent on modulation or on a change in the constant of stimulus-receptor binding but depended on a shedding of the membrane's receptor elements into solution. The magnitude of inhibition correlated with the oxygen concentration in the exposed suspension. Antioxidants (dithiothreitol and ionol) inhibited the shedding of receptor elements. The microwave exposure did not cause an accumulation of products from the peroxidation of lipids (POL). Ascorbate-dependent or non-enzymatic POL was not responsible for the inhibition, and POL was not found in other model systems. However, enzymatic POL mechanisms in localized areas of receptor binding remain a possibility.

Platano D, Mesirca P, Paffi A, Pellegrino M, Liberti M, Apollonio F, Bersani F, Aicardi G. Acute exposure to low-level CW and GSM-modulated 900 MHz radiofrequency does not affect Ba(2+) currents through voltage-gated calcium channels in rat cortical neurons. *Bioelectromagnetics*. 2007 Jul 9; [Epub ahead of print]

We have studied the non-thermal effects of radiofrequency (RF) electromagnetic fields (EMFs) on Ba(2+) currents ($I_{Ba^{2+}}$) through voltage-gated calcium channels (VGCC), recorded in primary cultures of rat cortical neurons using the patch-clamp technique. To assess whether low-level acute RF field exposure could modify the amplitude and/or the voltage-dependence of $I_{Ba^{2+}}$, Petri dishes containing cultured neurons were exposed for 1-3 periods of 90 s to 900 MHz RF-EMF continuous wave (CW) or amplitude-modulated according to global system mobile communication standard (GSM) during whole-cell recording. The specific absorption rates (SARs) were 2 W/kg for CW and 2 W/kg (time average value) for GSM-modulated signals, respectively. The results obtained indicate that single or multiple acute exposures to either CW or GSM-modulated 900 MHz RF-EMFs do not significantly alter the current amplitude or the current-voltage relationship of $I_{Ba^{2+}}$, through VGCC.

Preece, AW, Iwi, G, Davies-Smith, A, Wesnes, K, Butler, S, Lim, E, Varey, A, Effect of a 915-MHz simulated mobile phone signal on cognitive function in man. *Int J Radiat Biol* 75(4):447-456, 1999.

PURPOSE: To examine whether a simulated mobile telephone transmission at 915 MHz has an effect on cognitive function in man. **MATERIALS AND METHODS:** Thirty-six subjects in two groups were each given two training sessions and then three test sessions in a randomized three-way cross-over design. About 1 W mean power at 915 MHz from a quarter-wave antenna mounted on a physical copy of an analogue phone, as a sine wave, or modulated at 217 Hz with 12.5% duty cycle, or no power, was applied to the left squamous temple region of the subjects while they undertook a series of cognitive function tests lasting approximately 25-30 min. The second group was investigated for sleep, consumption of alcohol and beverages, and any other substances that might affect performance. **RESULTS:** In both groups, the only test affected was the choice reaction time and this showed as an increase in speed (a decrease in reaction time). There were no changes in word, number or picture recall, or in spatial memory. While an effect of visit-order was evident suggesting a learning effect of repeat tests, the design of the study allowed for this. Additionally, there was no systematic error introduced as a result of consumption of substances or sleep time. **CONCLUSIONS:** There was evidence of an increase in responsiveness, strongly in the analogue and less in the digital simulation, in choice reaction time. This could be associated with an effect on the angular gyrus that acts as an interface between the visual and speech centres and which lies directly under and on the same side as the antenna. Such an effect could be consistent with mild localized heating, or possibly a non-thermal response, which is nevertheless power-dependent.

Preece AW, Goodfellow S, Wright MG, Butler SR, Dunn EJ, Johnson Y, Manktelow TC, Wesnes K. Effect of 902 MHz mobile phone transmission on cognitive function in children. *Bioelectromagnetics*. 2005 Jun 1; [Epub ahead of print]

We examine whether a standard mobile exposure at 902 MHz has a significant effect on cognitive function in 18 children 10-12 years of age. These were in a single group in which each child was given a single training session and then three test sessions in a randomized, three-way crossover design, using the cognitive drug research (CDR) cognitive assessment system. Exposures were 0, 0.025, or 0.25 W from a standard Nokia 3110 mobile phone handset mounted on a plastic headset in normal use position. The results of testing showed that the baseline (0 W) performance for the reaction time measurements was considerably slower than for the comparable measures in adult. There was a tendency for reaction time to be shorter during exposure to radiation than in the sham (baseline) condition, an effect that was most marked for simple

reaction time. However, no effects reached statistical significance after Bonferroni correction. Therefore, we conclude that this study on 18 children did not replicate our earlier finding in adults that exposure to microwave radiation was associated with a reduction in reaction time. It should be noted that the present study investigated the effects of radiation from a GSM handset, whereas in our previous study the effect on reaction time was observed only with a more powerful analogue handset.

Pyrpasopoulou A, Kotoula V, Cheva A, Hytioglou P, Nikolakaki E, Magras IN, Xenos TD, Tsiboukis TD, Karkavelas G. Bone morphogenetic protein expression in newborn rat kidneys after prenatal exposure to radiofrequency radiation. *Bioelectromagnetics* 25(3):216-227, 2004.

Effects of nonthermal radiofrequency radiation (RFR) of the global system of mobile communication (GSM) cellular phones have been as yet mostly studied at the molecular level in the context of cellular stress and proliferation, as well as neurotransmitter production and localization. In this study, a simulation model was designed for the exposure of pregnant rats to pulsed GSM-like RFR (9.4 GHz), based on the different resonant frequencies of man and rat. The power density applied was 5 microW/cm², in order to avoid thermal electromagnetic effects as much as possible. Pregnant rats were exposed to RFR during days 1-3 postcoitum (p.c.) (embryogenesis, pre-implantation) and days 4-7 p.c. (early organogenesis, peri-implantation). Relative expression and localization of bone morphogenetic proteins (BMP) and their receptors (BMPR), members of a molecular family currently considered as major endocrine and autocrine morphogens and known to be involved in renal development, were investigated in newborn kidneys from RFR exposed and sham irradiated (control) rats. Semi-quantitative duplex RT-PCR for BMP-4, -7, BMPR-IA, -IB, and -II showed increased BMP-4 and BMPR-IA, and decreased BMPR-II relative expression in newborn kidneys. These changes were statistically significant for BMP-4, BMPR-IA, and -II after exposure on days 1-3 p.c. ($P < .001$ each), and for BMP-4 and BMPR-IA after exposure on days 4-7 p.c. ($P < .001$ and $P = .005$, respectively). Immunohistochemistry and in situ hybridization (ISH) showed aberrant expression and localization of these molecules at the histological level. Our findings suggest that GSM-like RFR interferes with gene expression during early gestation and results in aberrations of BMP expression in the newborn. These molecular changes do not appear to affect renal organogenesis and may reflect a delay in the development of this organ. The differences of relative BMP expression after different time periods of exposure indicate the importance of timing for GSM-like RFR effects on embryonic development.

Outob SS, Chauhan V, Bellier PV, Yauk CL, Douglas GR, Berndt L, Williams A, Gajda GB, Lemay E, Thansandote A, McNamee JP. Microarray gene expression profiling of a human glioblastoma cell line exposed in vitro to a 1.9 GHz pulse-modulated radiofrequency field. *Radiat Res.* 165(6):636-644, 2006.

The widespread use of mobile phones has led to public concerns about the health effects associated with exposure to radiofrequency (RF) fields. The paramount concern of most persons relates to the potential of these fields to cause cancer. Unlike ionizing radiation, RF fields used for mobile telecommunications (800-1900 MHz) do not possess sufficient energy to directly damage DNA. Most rodent bioassay and in vitro genotoxicity/mutation studies have reported that RF fields at non-thermal levels have no direct mutagenic, genotoxic or carcinogenic effects. However, some evidence has suggested that RF fields may cause detectable postexposure changes in gene expression. Therefore, the purpose of this study was to assess the ability of exposure to a 1.9 GHz pulse-modulated RF field for 4 h at specific absorption rates (SARs) of 0.1, 1.0 and 10.0 W/kg to affect global gene expression in U87MG glioblastoma cells. We found no evidence that non-thermal RF fields can affect gene expression in cultured U87MG cells relative to the nonirradiated control groups, whereas exposure to heat shock at 43 degrees C for 1 h up-regulated a number of typical stress-responsive genes in the positive control group. Future studies will assess the effect of RF fields on other cell lines and on gene expression in the mouse brain after in vivo exposure.

Rao VS, Titushkin IA, Moros EG, Pickard WF, Thatté HS, Cho MR. Nonthermal effects of radiofrequency-field exposure on calcium dynamics in stem cell-derived neuronal cells: elucidation of calcium pathways. *Radiat Res.* 169(3):319-329, 2008.

Intracellular Ca(2+) spikes trigger cell proliferation, differentiation and cytoskeletal reorganization. In addition to Ca(2+) spiking that can be initiated by a ligand binding to its receptor, exposure to electromagnetic stimuli has also been shown to

alter Ca^{2+} dynamics. Using neuronal cells differentiated from a mouse embryonic stem cell line and a custom-built, frequency-tunable applicator, we examined in real time the altered Ca^{2+} dynamics and observed increases in the cytosolic Ca^{2+} in response to nonthermal radiofrequency (RF)-radiation exposure of cells from 700 to 1100 MHz. While about 60% of control cells (not exposed to RF radiation) were observed to exhibit about five spontaneous Ca^{2+} spikes per cell in 60 min, exposure of cells to an 800 MHz, 0.5 W/kg RF radiation, for example, significantly increased the number of Ca^{2+} spikes to 15.7 ± 0.8 ($P < 0.05$). The increase in the Ca^{2+} spiking activities was dependent on the frequency but not on the SAR between 0.5 to 5 W/kg. Using pharmacological agents, it was found that both the N-type Ca^{2+} channels and phospholipase C enzymes appear to be involved in mediating increased Ca^{2+} spiking. Interestingly, microfilament disruption also prevented the Ca^{2+} spikes. Regulation of Ca^{2+} dynamics by external physical stimulation such as RF radiation may provide a noninvasive and useful tool for modulating the Ca^{2+} -dependent cellular and molecular activities of cells seeded in a 3D environment for which only a few techniques are currently available to influence the cells.

Regel SJ, Negovetic S, Roosli M, Berdinas V, Schuderer J, Huss A, Lott U, Kuster N, Achermann P. UMTS Base Station-like Exposure, Well-Being, and Cognitive Performance. *Environ Health Perspect.* 114(8):1270-1275, 2006.

Background: Radio-frequency electromagnetic fields (RF EMF) of mobile communication systems are widespread in the living environment, yet their effects on humans are uncertain despite a growing body of literature. Objectives: We investigated the influence of a Universal Mobile Telecommunications System (UMTS) base station-like signal on well-being and cognitive performance in subjects with and without self-reported sensitivity to RF EMF. Methods: We performed a controlled exposure experiment (45 min at an electric field strength of 0, 1, or 10 V/m, incident with a polarization of 45 degrees from the left back side of the subject, weekly intervals) in a randomized, double-blind crossover design. A total of 117 healthy subjects (33 self-reported sensitive, 84 nonsensitive subjects) participated in the study. We assessed well-being, perceived field strength, and cognitive performance with questionnaires and cognitive tasks and conducted statistical analyses using linear mixed models. Organ-specific and brain tissue-specific dosimetry including uncertainty and variation analysis was performed. Results: In both groups, well-being and perceived field strength were not associated with actual exposure levels. We observed no consistent condition-induced changes in cognitive performance except for two marginal effects. At 10 V/m we observed a slight effect on speed in one of six tasks in the sensitive subjects and an effect on accuracy in another task in nonsensitive subjects. Both effects disappeared after multiple end point adjustment. Conclusions: In contrast to a recent Dutch study, we could not confirm a short-term effect of UMTS base station-like exposure on well-being. The reported effects on brain functioning were marginal and may have occurred by chance. Peak spatial absorption in brain tissue was considerably smaller than during use of a mobile phone. No conclusions can be drawn regarding short-term effects of cell phone exposure or the effects of long-term base station-like exposure on human health. Key words: base station, cognitive function, electromagnetic hypersensitivity, human exposure, mobile phones, RF EMF.

Regel SJ, Tinguely G, Schuderer J, Adam M, Kuster N, Landolt HP, Achermann P. Pulsed radio-frequency electromagnetic fields: dose-dependent effects on sleep, the sleep EEG and cognitive performance. *J Sleep Res.* 16(3):253-258, 2007.

To establish a dose-response relationship between the strength of electromagnetic fields (EMF) and previously reported effects on the brain, we investigated the influence of EMF exposure by varying the signal intensity in three experimental sessions. The head of 15 healthy male subjects was unilaterally exposed for 30 min prior to sleep to a pulse-modulated EMF (GSM handset like signal) with a 10 g-averaged peak spatial specific absorption rate of (1) 0.2 W kg⁻¹, (2) 5 W kg⁻¹, or (3) sham exposed in a double-blind, crossover design. During exposure, subjects performed two series of three computerized cognitive tasks, each presented in a fixed order [simple reaction time task, two-choice reaction time task (CRT), 1-, 2-, 3-back task]. Immediately after exposure, night-time sleep was polysomnographically recorded for 8 h. Sleep architecture was not affected by EMF exposure. Analysis of the sleep electroencephalogram (EEG) revealed a dose-dependent increase of power in the spindle frequency range in non-REM sleep. Reaction speed decelerated with increasing field intensity in the 1-back task, while accuracy in the CRT and N-back task were not affected in a dose-dependent manner. In summary, this study reveals first indications of a dose-response relationship between EMF field intensity and its effects on brain physiology as demonstrated by changes in the sleep EEG and in cognitive performance.

Remondini D, Nylund R, Reivinen J, Pouletier de Gannes F, Veyret B, Lagrove I, Haro E, Trillo MA, Capri M, Franceschi C, Schlatterer K, Gminski R, Fitzner R, Tauber R, Schuderer J, Kuster N, Leszczynski D, Bersani F, Maercker C. Gene expression changes in human cells after exposure to mobile phone microwaves. *Proteomics*. 2006 Jul 28; [Epub ahead of print]

Possible biological effects of mobile phone microwaves were investigated in vitro. In this study, which was part of the 5FP EU project REFLEX (Risk Evaluation of Potential Environmental Hazards From Low-Energy Electromagnetic Field Exposure Using Sensitive in vitro Methods), six human cell types, immortalized cell lines and primary cells, were exposed to 900 and 1800 MHz. RNA was isolated from exposed and sham-exposed cells and labeled for transcriptome analysis on whole-genome cDNA arrays. The results were evaluated statistically using bioinformatics techniques and examined for biological relevance with the help of different databases. NB69 neuroblastoma cells, T lymphocytes, and CHME5 microglial cells did not show significant changes in gene expression. In EA.hy926 endothelial cells, U937 lymphoblastoma cells, and HL-60 leukemia cells we found between 12 and 34 up- or down-regulated genes. Analysis of the affected gene families does not point towards a stress response. However, following microwave exposure, some but not all human cells might react with an increase in expression of genes encoding ribosomal proteins and therefore up-regulating the cellular metabolism.

Repacholi, MH, Basten, A, Gebiski, V, Noonan, D, Finnie, J, Harris, AW, Lymphomas in E mu-Pim1 transgenic mice exposed to pulsed 900 MHZ electromagnetic fields. *Radiat Res* 147(5):631-640, 1997.

Whether radiofrequency (RF) fields are carcinogenic is controversial; epidemiological data have been inconclusive and animal tests limited. The aim of the present study was to determine whether long-term exposure to pulse-modulated RF fields similar to those used in digital mobile telecommunications would increase the incidence of lymphoma in E mu-Pim1 transgenic mice, which are moderately predisposed to develop lymphoma spontaneously. One hundred female E mu-Pim1 mice were sham-exposed and 101 were exposed for two 30-min periods per day for up to 18 months to plane-wave fields of 900 MHz with a pulse repetition frequency of 217 Hz and a pulse width of 0.6 ms. Incident power densities were 2.6-13 W/m² and specific absorption rates were 0.008-4.2 W/kg, averaging 0.13-1.4 W/kg. Lymphoma risk was found to be significantly higher in the exposed mice than in the controls (OR = 2.4. P = 0.006, 95% CI = 1.3-4.5). Follicular lymphomas were the major contributor to the increased tumor incidence. Thus long-term intermittent exposure to RF fields can enhance the probability that mice carrying a lymphomagenic oncogene will develop lymphomas. We suggest that such genetically cancer-prone mice provide an experimental system for more detailed assessment of dose-response relationships for risk of cancer after RF-field exposure.

Rezk AY, Abdulqawi K, Mustafa RM, Abo El-Azm TM, Al-Inany H. Fetal and neonatal responses following maternal exposure to mobile phones. *Saudi Med J*. 29(2):218-223, 2008.

OBJECTIVE: To study fetal and neonatal heart rate (HR) and cardiac output (COP), following acute maternal exposure to electromagnetic fields (EMF) emitted by mobile phones. **METHODS:** The present study was carried out at Benha University Hospital and El-Shorouq Hospital, Cairo, Egypt, from October 2003 to March 2004. Ninety women with uncomplicated pregnancies aged 18-33 years, and 30 full term healthy newborn infants were included. The pregnant mothers were exposed to EMF emitted by mobile telephones while on telephone-dialing mode for 10 minutes during pregnancy and after birth. The main outcome were measurements of fetal and neonatal HR and COP. **RESULTS:** A statistical significant increase in fetal and neonatal HR, and statistical significant decrease in stroke volume and COP before and after use of mobile phone were noted. All these changes are attenuated with increase in gestational age. **CONCLUSION:** Exposure of pregnant women to mobile phone significantly increase fetal and neonatal HR, and significantly decreased the COP.

Ribeiro EP, Rhoden EL, Horn MM, Rhoden C, Lima LP, Toniolo L, Effects of Subchronic Exposure to Radio Frequency From a Conventional Cellular Telephone on Testicular Function in Adult Rats. *J Urol* 177:395-399, 2007.

Purpose

We investigated the effects of subchronic exposure to radio frequency emitted from a conventional cellular telephone on the testicular function in adult rats.

Materials and Methods

A total of 16 male Wistar rats at age 30 days were randomly divided into 2 groups, including experimental and control groups. The experimental group was exposed to radio frequency emitted from a conventional GSM (global system for mobile communications) cellular telephone (1,835 to 1,850 MHz) for 1 hour daily during 11 weeks. Rectal temperature was measured before and after the exposure period. Testicular and epididymal weight, lipid peroxidation levels in these organs, serum total testosterone and the epididymal sperm count were evaluated. Maturation phase spermatid retention at stage IX-X, interstitial infiltration, cellular vacuolation and multinucleate giant cells were among the qualitative testicular histopathological end points analyzed. Each rat had 10 consecutive round seminiferous tubules at stage VII-VIII evaluated for the mean seminiferous tubular diameter measurement, the crude histological count of round spermatids, pachytene spermatocytes and Sertoli's cells with evident nucleoli, and the true histological count (Abercrombie's correction factor) of round spermatids and pachytene spermatocytes.

Results

Mean rectal temperature did not alter following exposure. There was no statistical difference between the control and experimental groups in any end points evaluated.

Conclusions

The current study shows that the low intensity pulsed radio frequency emitted by a conventional cellular telephone does not impair testicular function in adult rats.

Roosli M, Michel G, Kuehni CE, Spoerri A. Cellular telephone use and time trends in brain tumour mortality in Switzerland from 1969 to 2002. *Eur J Cancer Prev.* 16(1):77-82. 2007.

A rising concern exists that with the widespread use of mobile communication technologies, the incidence of brain tumours may increase. On the basis of data from the Swiss national mortality registry from 1969 to 2002, annual age-standardized brain tumour mortality rates per 100 000 person-years were calculated using the European standard population. Time trend analyses were performed by the Poisson regression for six different age groups in men and women separately. The study period was divided into two intervals: before and after 1987, when the analogue mobile technology was introduced in Switzerland. Age-standardized brain tumour mortality rates ranged between 3.7 and 6.7 for men and 2.5 and 4.4 for women per 100 000 person-years. For the whole study period, a significant increase in brain tumour mortality was observed for men and women in the older age groups (60-74 and 75+ years) but not in the younger ones in whom mobile phone use was more prevalent. Time trend analyses restricted to data from 1987 onwards revealed relatively stable brain tumour mortality rates in all age groups. For instance, the annual change in brain tumour mortality rate for the 45-59-year age group was -0.3% (95% confidence interval: -1.7; 1.1) for men and -0.4% (95% confidence interval: -2.2; 1.3) for women. We conclude that after the introduction of mobile phone technology in Switzerland, brain tumour mortality rates remained stable in all age groups. Our results suggest that mobile phone use is not a strong risk factor in the short term for mortality from brain tumours. Ecological analyses like this, however, are limited in their ability to reveal potentially small increases in risk for diseases with a long latency period.

Roschke, J, Mann, K, No short-term effects of digital mobile radio telephone on the awake human electroencephalogram. *Bioelectromagnetics* 18(2):172-176, 1997.

A recent study reported the results of an exploratory study of alterations of the quantitative sleep profile due to the effects of a digital mobile radio telephone. Rapid eye movement (REM) was suppressed, and the spectral power density in the 8-13 Hz frequency range during REM sleep was altered. The aim of the present study was to illuminate the influence of digital mobile radio telephone on the awake electroencephalogram (EEG) of healthy subjects. For this purpose, we investigated 34 male subjects in a single-blind cross-over design experiment by measuring spontaneous EEGs under closed-eyes condition from scalp positions C3 and C4 and comparing the effects of an active (0.05 mW/cm²) and an inactive digital mobile radio telephone

(GSM) system. During exposure of nearly 3.5 min to the 900 MHz electromagnetic field pulsed at a frequency of 217 Hz and with a pulse width of 580 microseconds, we could not detect any difference in the awake EEGs in terms of spectral power density measures.

Roti Roti JL , Malyapa RS, Bisht KS, Ahern EW, Moros EG, Pickard WF, Straube WL, Neoplastic Transformation in C3H 10T(1/2) Cells after Exposure to 835.62 MHz FDMA and 847.74 MHz CDMA Radiations. *Radiat Res* 155(1):239-247, 2001.

Roti Roti, J. L., Malyapa, R. S., Bisht, K. S., Ahern, E. W., Moros, E. G., Pickard, W. F. and Straube, W. L. Neoplastic Transformation in C3H 10T(1/2) Cells after Exposure to 835.62 MHz FDMA and 847.74 MHz CDMA Radiations. The effect of radiofrequency (RF) radiation in the cellular phone communication range (835.62 MHz frequency division multiple access, FDMA; 847.74 MHz code division multiple access, CDMA) on neoplastic transformation frequency was measured using the in vitro C3H 10T(1/2) cell transformation assay system. To determine if 835.62 MHz FDMA or 847.74 MHz CDMA radiations have any genotoxic effects that induce neoplastic transformation, C3H 10T(1/2) cells were exposed at 37 degrees C to either of the above radiations [each at a specific absorption rate (SAR) of 0.6 W/kg] or sham-exposed at the same time for 7 days. After the culture medium was changed, the cultures were transferred to incubators and refed with fresh growth medium every 7 days. After 42 days, the cells were fixed and stained with Giemsa, and transformed foci were scored. To determine if exposure to 835.62 MHz FDMA or 847.74 MHz CDMA radiation has any epigenetic effects that can promote neoplastic transformation, cells were first exposed to 4.5 Gy of X rays to induce the transformation process and then exposed to the above radiations (SAR = 0.6 W/kg) in temperature-controlled irradiators with weekly refeeding for 42 days. After both the 7-day RF exposure and the 42-day RF exposure after X irradiation, no statistically significant differences in the transformation frequencies were observed between incubator controls, the sham-exposed (maintained in irradiators without power to the antenna), and the 835.62 MHz FDMA or 847.74 MHz CDMA-exposed groups.

Russo R, Fox E, Cinel C, Boldini A, Defeyter MA, Mirshekar-Syahkal D, Mehta A. Does acute exposure to mobile phones affect human attention? *Bioelectromagnetics*. 2005 Nov 22; [Epub ahead of print]

Recent studies have indicated that acute exposure to low level radiofrequency (RF) electromagnetic fields generated by mobile phones affects human cognition. However, the relatively small samples used, in addition to methodological problems, make the outcomes of these studies difficult to interpret. In our study we tested a large sample of volunteers (168) using a series of cognitive tasks apparently sensitive to RF exposure (a simple reaction task, a vigilance task, and a subtraction task). Participants performed those tasks twice, in two different sessions. In one session they were exposed to RFs, with half of subjects exposed to GSM signals and the other half exposed to CW signals, while in the other session they were exposed to sham signals. No significant effects of RF exposure on performance for either GSM or CW were found, independent of whether the phone was positioned on the left or on the right side.

Sadetzki S, Chetrit A, Jarus-Hakak A, Cardis E, Deutch Y, Duvdevani S, Zultan A, Novikov I, Freedman L, Wolf M. Cellular phone use and risk of benign and malignant parotid gland tumors--a nationwide case-control study. *Am J Epidemiol*. 167(4):457-467, 2008.

The objective of this nationwide study was to assess the association between cellular phone use and development of parotid gland tumors (PGTs). The methods were based on the international INTERPHONE study that aimed to evaluate possible adverse effects of cellular phone use. The study included 402 benign and 58 malignant incident cases of PGTs diagnosed in Israel at age 18 years or more, in 2001-2003, and 1,266 population individually matched controls. For the entire group, no increased risk of PGTs was observed for ever having been a regular cellular phone user (odds ratio = 0.87; p = 0.3) or for any other measure of exposure investigated. However, analysis restricted to regular users or to conditions that may yield higher levels of exposure (e.g., heavy use in rural areas) showed consistently elevated risks. For ipsilateral use, the odds ratios in the highest category of cumulative number of calls and call time without use of hands-free devices were 1.58 (95% confidence interval: 1.11, 2.24) and 1.49 (95% confidence interval: 1.05, 2.13), respectively. The risk for contralateral use was not significantly different from 1. A positive dose-response trend was found for these measurements. Based on the largest number of benign PGT patients reported to date, our results suggest an association between cellular phone use and PGTs.

Sakuma N, Komatsubara Y, Takeda H, Hirose H, Sekijima M, Nojima T, Miyakoshi J. DNA strand breaks are not induced in human cells exposed to 2.1425 GHz band CW and W-CDMA modulated radiofrequency fields allocated to mobile radio base stations. Bioelectromagnetics. 27:51-57, 2006.

We conducted a large-scale in vitro study focused on the effects of low level radiofrequency (RF) fields from mobile radio base stations employing the International Mobile Telecommunication 2000 (IMT-2000) cellular system in order to test the hypothesis that modulated RF fields may act as a DNA damaging agent. First, we evaluated the responses of human cells to microwave exposure at a specific absorption rate (SAR) of 80 mW/kg, which corresponds to the limit of the average whole body SAR for general public exposure defined as a basic restriction in the International Commission on Non-Ionizing Radiation Protection (ICNIRP) guidelines. Second, we investigated whether continuous wave (CW) and Wideband Code Division Multiple Access (W-CDMA) modulated signal RF fields at 2.1425 GHz induced different levels of DNA damage. Human glioblastoma A172 cells and normal human IMR-90 fibroblasts from fetal lungs were exposed to mobile communication frequency radiation to investigate whether such exposure produced DNA strand breaks in cell culture. A172 cells were exposed to W-CDMA radiation at SARs of 80, 250, and 800 mW/kg and CW radiation at 80 mW/kg for 2 and 24 h, while IMR-90 cells were exposed to both W-CDMA and CW radiations at a SAR of 80 mW/kg for the same time periods. Under the same RF field exposure conditions, no significant differences in the DNA strand breaks were observed between the test groups exposed to W-CDMA or CW radiation and the sham exposed negative controls, as evaluated immediately after the exposure periods by alkaline comet assays. Our results confirm that low level exposures do not act as a genotoxicant up to a SAR of 800 mW/kg.

Salama N, Kishimoto T, Kanayama HO. Effects of exposure to a mobile phone on testicular function and structure in adult rabbit. Int J Androl. 2008 Dec 2. [Epub ahead of print]

Summary The accumulating effects of exposure to electromagnetic radiation emitted by a conventional mobile phone (standby position) on the testicular function and structure are not yet fully investigated. To study these effects longitudinally, a total of 24 adult male rabbits were randomly and equally divided into three groups. Rabbits in the first (phone) group were exposed, in specially designed cages, to radio frequency emitted from the mobile phone (800 MHz) in a standby position opposite to that of testes for 8 h daily for 12 weeks. The second group consisted of the stress controls which were kept in the same kind of cages to appreciate any cage-induced anxiety. The third group included the ordinary controls which were kept in the conventional roomy cages. Semen analysis and sperm function tests (viability, hypo-osmotic swelling and acridine orange) were conducted weekly. Histological testicular sections and serum total testosterone were also evaluated. A drop in the sperm concentration appeared in the phone group at week 6. This became statistically significant at week 8, compared with the two control (stress and ordinary) groups (133, 339 and 356 x 10⁶/mL, respectively) and to the initial sperm count (341 x 10⁶/mL) of this group. Motile sperm population showed similarity amongst the three study groups until week 10 when it declined significantly, and thereafter in the phone and stress control groups, with more significant decline in the phone animals (50, 61 and 72.4%, respectively). Histological examination showed also a significant decrease in the diameter of seminiferous tubules in the phone group vs. the stress and ordinary controls (191 μ m vs. 206 and 226 μ m, respectively). The other study points did not show any difference. In conclusion, low intensity pulsed radio frequency emitted by a conventional mobile phone kept in the standby position could affect the testicular function and structure in the adult rabbit.

Salford LG, Brun A, Sturesson K, Eberhardt JL, Persson BR Permeability of the blood-brain barrier induced by 915 MHz electromagnetic radiation, continuous wave and modulated at 8, 16, 50, and 200 Hz. Microsc Res Tech 27(6):535-542, 1994.

Biological effects of electromagnetic fields (EMF) on the blood-brain barrier (BBB) can be studied in sensitive and specific models. In a previous investigation of the permeability of the blood-brain barrier after exposure to the various EMF-components of proton magnetic resonance imaging (MRI), we found that the exposure to MRI induced leakage of Evans Blue labeled proteins normally not passing the BBB of rats [Salford et al. (1992), in: Resonance Phenomena in Biology, Oxford University Press, pp. 87-91]. In the present investigation we exposed male and female Fischer 344 rats in a transverse electromagnetic transmission line chamber to microwaves of 915 MHz as continuous wave (CW) and pulse-modulated with repetition rates of 8, 16, 50, and 200 s⁻¹. The specific energy absorption rate (SAR) varied between 0.016 and 5 W/kg. The rats were not anesthetized during the 2-hour exposure. All animals were sacrificed by perfusion-fixation of the brains under chloral hydrate anesthesia about 1 hour after the exposure. The brains were perfused with saline for 3-

4 minutes, and thereafter fixed in 4% formaldehyde for 5-6 minutes. Central coronal sections of the brains were dehydrated and embedded in paraffin and sectioned at 5 microns. Albumin and fibrinogen were demonstrated immunohistochemically. The results show albumin leakage in 5 of 62 of the controls and in 56 of 184 of the animals exposed to 915 MHz microwaves. Continuous wave resulted in 14 positive findings of 35, which differ significantly from the controls ($P = 0.002$).

Salford LG, Brun A, Persson BRR, Brain tumour development in rats exposed to electromagnetic fields used in wireless cellular communication. *Wireless network* 3: 463-469, 1997.

It has been suggested that electromagnetic fields (EMF) act as promoters late in the carcinogenesis process. To date, however, there is no convincing laboratory evidence that EMFs cause tumour promotion at non-thermal exposure levels. Therefore the effects of exposure to electromagnetic fields were investigated in a rat brain glioma model. Some of the exposures correspond to electromagnetic fields used in wireless communication. Microwaves at 915 MHz were used both as continuous waves (1 W), and pulse-modulated at 4, 8, 16 and 217 Hz in 0.57 ms pulses and 50 Hz in 6.67 ms pulses (2 W per pulse). Fischer 344 rats of both sexes were used in the experiments. By stereotaxic technique rat glioma cells (RG2 and N32) were injected into the head of the right caudate nucleus in 154 pairs of rats, exposed and matched controls. Starting on day 5 after inoculation, the animals were exposed for 7 hours a day, 5 days a week during 2-3 weeks. Exposed animals were kept unanaesthetized in well-ventilated TEM cells producing 915 MHz continuous or modulated microwaves. Their matched controls were kept in identical TEM cells without EMF exposure. All brains were examined histopathologically and the tumour size was estimated as the volume of an ellipsoid. Our study of 154 matched pairs of rats does not show any significant difference in tumour size between animals exposed to 915 MHz, and those not exposed. Thus our results do not support that even an extensive daily exposure to EMF promotes tumour growth when given from the fifth day after the start of tumour growth in the rat brain until the sacrifice of the animal after about 16 days.

Salford LG, Brun AR, Eberhardt JL, Malmgren L, Persson BRR, Nerve cell damage in mammalian brain after exposure to microwaves from GSM mobile phones. *Environ Health Persp* 111:881-883, 2003.

The possible risks of radio-frequency electromagnetic fields for the human body is a growing concern for the society. We have earlier shown that weak pulsed microwaves give rise to a significant leakage of albumin through the blood-brain barrier (BBB). Now we have investigated whether a pathological leakage over the BBB might be combined with damage to the neurons. Three groups of each 8 rats were exposed for 2 hours to GSM mobile phone electromagnetic fields of different strengths. We found, and present here for the first time, highly significant ($p < 0.002$) evidence for neuronal damage in both the cortex, the hippocampus and the basal ganglia in the brains of exposed rats.

Sanchez S, Milochau A, Ruffie G, Poullietier de Gannes F, Lagroye I, Haro E, Surleve-Bazeille JE, Billaudel B, Lassegues M, Veyret B. Human skin cell stress response to GSM-900 mobile phone signals. *FEBS J*. 2006 Nov 9; [Epub ahead of print]

In recent years, possible health hazards due to radiofrequency radiation (RFR) emitted by mobile phones have been investigated. Because several publications have suggested that RFR is stressful, we explored the potential biological effects of Global System for Mobile phone communication at 900 MHz (GSM-900) exposure on cultures of isolated human skin cells and human reconstructed epidermis (hRE) using human keratinocytes. As cell stress markers, we studied Hsc70, Hsp27 and Hsp70 heat shock protein (HSP) expression and epidermis thickness, as well as cell proliferation and apoptosis. Cells were exposed to GSM-900 under optimal culture conditions, for 48 h, using a specific absorption rate (SAR) of 2 W.kg⁻¹. This SAR level represents the recommended limit for local exposure to a mobile phone. The various biological parameters were analysed immediately after exposure. Apoptosis was not induced in isolated cells and there was no alteration in hRE thickness or proliferation. No change in HSP expression was observed in isolated keratinocytes. By contrast, a slight but significant increase in Hsp70 expression was observed in hREs after 3 and 5 weeks of culture. Moreover, fibroblasts showed a significant decrease in Hsc70, depending on the culture conditions. These results suggest that adaptive cell behaviour in response to RFR exposure, depending on the cell type and culture conditions, is unlikely to have deleterious effects at the skin level.

Sanchez S, Masuda H, Billaudel B, Haro E, Anane R, Leveque P, Ruffie G, Lagroye I, Veyret B. Effect of GSM-900 and -1800 signals on the skin of hairless rats. II: 12-week chronic exposures. **Int J Radiat Biol.** 82(9):675-680, 2006.

Purpose: The purpose of this work was to determine whether the cellular components of Hairless-rat skin are affected by a chronic local exposure to non-ionizing radiations of Global Mobile Phone System: GSM-900 or -1800 radiations at specific absorption rate (SAR) 2.5 and 5 W/kg. **Materials and methods:** A selected part of the right back of five-week old female hairless rats was exposed or sham exposed (n = 8) for 2 h per day, 5 days a week, for 12 weeks to GSM-900 or -1800 signals using a loop-antenna. At the end of the experiment, skin biopsies were taken. **Results:** Analyses of skin sections using hematoxylin eosin saffron (HES) coloration showed no significant difference in skin thickness among the groups. Immunohistochemical analysis of basal lamella cells in radiofrequency radiation (RFR)-exposed epidermis showed that the ratio of the antigen Ki-67 (cellular proliferation marker) positive cells to total lamella cells remained within the range of the normal proliferation ratio. No significant differences in the level of filaggrin, collagen, and elastin were observed among the different groups. **Conclusions:** The results of this 12-week chronic study do not demonstrate major histological variations in the skin of hairless rats exposed to RFR used in mobile telephony (GSM-900 or -1800).

Sanchez, S., Haro, E., Ruffie, G., Veyret, B. and Lagroye, I. In Vitro Study of the Stress Response of Human Skin Cells to GSM-1800 Mobile Phone Signals Compared to UVB Radiation and Heat Shock. Radiat. Res. 167, 572-580, 2007.

The evolution of mobile phone technology is toward an increase of the carrier frequency up to 2.45 GHz. Absorption of radiofrequency (RF) radiation becomes more superficial as the frequency increases. This increasingly superficial absorption of RF radiation by the skin, which is the first organ exposed to RF radiation, may lead to stress responses in skin cells. We thus investigated the expression of three heat-shock proteins (HSP70, HSC70, HSP27) using immunohistochemistry and induction of apoptosis by flow cytometry on human primary keratinocytes and fibroblasts. A well-characterized exposure system, SXC 1800, built by the IT'IS foundation was used at 1800 MHz, with a 217 Hz modulation. We tested a 48-h exposure at an SAR of 2 W/kg (ICNIRP local exposure limit). Skin cells were also irradiated with a 600 mJ/cm² single dose of UVB radiation and subjected to heat shock (45 degrees C, 20 min) as positive controls for apoptosis and HSP expression, respectively. The results showed no effect of a 48-h GSM-1800 exposure at 2 W/kg on either keratinocytes or fibroblasts, in contrast to UVB-radiation or heat-shock treatments, which injured cells. We thus conclude that the GSM-1800 signal does not act as a stress factor on human primary skin cells in vitro.

Sanchez S, Masuda H, Ruffié G, De Gannes FP, Billaudel B, Haro E, Lévêque P, Lagroye I, Veyret B. Effect of GSM-900 and -1800 signals on the skin of hairless rats. III: Expression of heat shock proteins. **Int J Radiat Biol.** 2007 Sep 8;1-8 [Epub ahead of print]

Purpose: We previously reported the inability of Global System for Mobile communication (GSM) signals at 900 (GSM-900) and 1800 (GSM-1800) MegaHertz (MHz) to induce morphological and physiological changes in epidermis of Hairless rats. The present work aimed at investigating heat shock proteins (HSP) expression - as a cellular stress marker - in the skin of Hairless rats exposed to GSM-900 and -1800 signals. **Materials and methods:** We studied the expression of the Heat-shock cognate (Hsc) 70, and the inducible forms of the Heat-shock proteins (Hsp) 25 and 70. Rat skin was locally exposed using loop antenna and restrain rockets to test several Specific Absorption Rates (SAR) and exposure durations: (i) single exposure: 2 hours at 0 and 5 W/kg; (ii) repeated exposure: 2 hours per day, 5 days per week, for 12 weeks, at 0, 2.5, and 5 W/kg. HSP expression was detected on skin slices using immunolabeling in the epidermal area. **Results:** Our data indicated that neither single nor repeated exposures altered HSP expression in rat skin, irrespective of the GSM signal or SAR considered. **Conclusions:** Under our experimental conditions (local SAR <5 W/kg), there was no evidence that GSM signals alter HSP expression in rat skin.

Sandstrom M, Wilen J, Oftedal G, Hansson Mild K, Mobile phone use and subjective symptoms. Comparison of symptoms experienced by users of analogue and digital mobile phones. Occup Med (Lond) 51(1):25-35, 2001.

In 1995 many people reported symptoms such as headaches, feelings of discomfort, warmth behind/around or on the ear and difficulties concentrating while using mobile phones. The number of complaints was higher for people using the digital (GSM) system, i.e. with pulse modulated fields, than for those using the analogue (NMT) system. Our main

hypothesis was that GSM users experience more symptoms than NMT users. An epidemiological investigation was initiated including 6379 GSM users and 5613 NMT 900 users in Sweden, and 2500 from each category in Norway. The adjusted odds ratio did not indicate any increased risk for symptoms for GSM users compared with NMT 900 users. Our hypothesis was therefore disproved. However, we observed a statistically significant lower risk for sensations of warmth on the ear for GSM users compared with NMT 900 users. The same trend was seen in Norway for sensations of warmth behind/around the ear and in Sweden for headaches and fatigue. Factors distinguishing the two systems (radio frequency emission, phone temperatures and various ergonomic factors) may be responsible for these results, as well as for a secondary finding: a statistically significant association between calling time/number of calls per day and the prevalence of warmth behind/around or on the ear, headaches and fatigue.

Santini R, Seigne M, Bonhomme-Faivre L, Bouffet S, Defrasne E, Sage M. Symptoms experienced by users of digital cellular phones: a pilot study in a French engineering school. *Pathol Biol (Paris)* 49(3):222-226, 2001.

[Article in French]

A survey study, using questionnaire, was conducted in 161 students and workers in a French engineering school on symptoms experienced during use of digital cellular phones. A significant increase in concentration difficulty ($p < 0.05$) was reported by users of 1800-MHz (DCS) cellular phones compared to 900-MHz (GSM) phone users. In users of cellular phones, women significantly ($p < 0.05$) complained more often of sleep disturbance than men. This sex difference for sleep complaint is not observed between women and men non-users of cellular phone. The use of both cellular phones and VDT significantly ($p < 0.05$) increased concentration difficulty. Digital cellular phone users also significantly ($p < 0.05$) more often complained of discomfort, warmth, and picking on the ear during phone conversation in relation with calling duration per day and number of calls per day. The complaint warmth on the ear might be a signal to users for stopping the call.

Santini R, Santini P, Danze JM, Le Ruz P, Seigne M. Study of the health of people living in the vicinity of mobile phone base stations: I. Influence of distance and sex. *Pathol Biol (Paris)* 50(6):369-373, 2002.

[Article in French]

A survey study using questionnaire was conducted in 530 people (270 men, 260 women) living or not in vicinity of cellular phone base stations, on 18 Non Specific Health Symptoms. Comparisons of complaints frequencies (CHI-SQUARE test with Yates correction) in relation with distance from base station and sex, show significant ($p < 0.05$) increase as compared to people living > 300 m or not exposed to base station, till 300 m for tiredness, 200 m for headache, sleep disturbance, discomfort, etc. 100 m for irritability, depression, loss of memory, dizziness, libido decrease, etc. Women significantly more often than men ($p < 0.05$) complained of headache, nausea, loss of appetite, sleep disturbance, depression, discomfort and visual perturbations. This first study on symptoms experienced by people living in vicinity of base stations shows that, in view of radioprotection, minimal distance of people from cellular phone base stations should not be < 300 m.

Sarimov R, Malmgren L.O.G., Markova, E., Persson, B.R.R., Belyaev, I.Y. Nonthermal GSM microwaves affect chromatin conformation in human lymphocytes similar to heat shock. *IEEE Trans Plasma Sci* 32:1600-1608, 2004.

Here we investigated whether microwaves (MWs) of Global System for Mobile Communication (GSM) induce changes in chromatin conformation in human lymphocytes. Effects of MWs were studied at different frequencies in the range of 895-915 MHz in experiments with lymphocytes from seven healthy persons. Exposure was performed in transverse electromagnetic transmission line cell (TEM-cell) using a GSM test-mobile phone. All standard modulations included 2 W output power in the pulses, specific absorbed rate (SAR) being 5.4 mW/kg. Changes in chromatin conformation, which are indicative of stress response and genotoxic effects, were measured by the method of anomalous viscosity time dependencies (AVTD). Heat shock and treatment with the genotoxic agent camptothecin, were used as positive controls. 30-min exposure to MWs at 900 and 905 MHz resulted in statistically significant condensation of chromatin in lymphocytes from 1 of 3 tested donors. This condensation was similar to effects of heat shock within the temperature window of 40/spl deg/C-44/spl deg/C. Analysis of pooled data from all donors showed statistically significant effect of

30-min exposure to MWs. Stronger effects of MWs was found following 1-h exposure. In replicated experiments, cells from four out of five donors responded to 905 MHz. Responses to 915 MHz were observed in cells from 1 out of 5 donors, $p < 0.002$. Dependent on donor, condensation, 3 donors, or decondensation, 1 donor, of chromatin was found in response to 1-h exposure. Analysis of pooled data from all donors showed statistically significant effect of 1-h exposure to MWs. In cells from one donor, this effect was frequency-dependent ($p < 0.01$). Effects of MWs correlated statistically significantly with effects of heat shock and initial state of chromatin before exposure. MWs at 895 and 915 MHz affected chromatin conformation in transformed lymphocytes. The conclusion-GSM microwaves under specific conditions of exposure affected human lymphocytes similar to stress response. The data suggested that the MW effects differ at various GSM frequencies and vary between donors.

Scarfi MR, Freseghna AM, Villani P, Pinto R, Marino C, Sarti M, Altavista P, Sannino A, Lovisolo GA. Exposure to radiofrequency radiation (900 MHz, GSM signal) does not affect micronucleus frequency and cell proliferation in human peripheral blood lymphocytes: an interlaboratory study. *Radiat Res.* 165(6):655-663, 2006.

The objective of this study was to investigate whether 24 h exposure to radiofrequency electromagnetic fields similar to those emitted by mobile phones induces genotoxic effects and/or effects on cell cycle kinetics in cultured human peripheral blood lymphocytes. The effect of 900 MHz exposure (GSM signal) was evaluated at four specific absorption rates (SARs, 0, 1, 5 and 10 W/kg peak values). The exposures were carried out in wire patch cells under strictly controlled conditions of both temperature and dosimetry, and the induction of genotoxic effects was evaluated in lymphocyte cultures from 10 healthy donors by applying the cytokinesis-block micronucleus assay. Positive controls were provided by using mitomycin C. Two research groups were involved in the study, one at ENEA, Rome, and the other at CNR-IREA, Naples. Each laboratory tested five donors, and the resulting slides were scored by both laboratories. Following this experimental scheme, it was also possible to compare the results obtained by cross-scoring of slides. The results obtained provided no evidence for the existence of genotoxic or cytotoxic effects in the range of SARs investigated. These findings were confirmed in the two groups of five donors examined in the two laboratories and when the same slides were scored by two operators.

Schirmacher A, Winters S, Fischer S, Goeke J, Galla H, Kullnick U, Ringelstein EB, Stogbauer F, Electromagnetic fields (1.8 GHz) increase the permeability to sucrose of the blood-brain barrier in vitro. *Bioelectromagnetics* 21(5):338-345, 2000.

We report an investigation on the influence of high frequency electromagnetic fields (EMF) on the permeability of an in vitro model of the blood-brain barrier (BBB). Our model was a co-culture consisting of rat astrocytes and porcine brain capillary endothelial cells (BCEC). Samples were characterized morphologically by scanning electron microscopy and immunocytochemistry. The BBB phenotype of the BCEC was shown by the presence of zona occludens protein (ZO-1) as a marker for tight junctions and the close contact of the cells together with the absence of intercellular clefts. Permeability measurements using (14)C-sucrose indicated a physiological tightness which correlated with the morphological findings and verified the usefulness of our in vitro model. Samples were exposed to EMF conforming to the GSM1800-standard used in mobile telephones (1.8 GHz). The permeability of the samples was monitored over four days and compared with results of samples that were cultured identically but not exposed to EMF. Exposure to EMF increased permeability for (14)C-sucrose significantly compared to unexposed samples. The underlying pathophysiological mechanism remains to be investigated.

Schmid G, Sauter C, Stepansky R, Lobentanz IS, Zeitlhofer J. No influence on selected parameters of human visual perception of 1970 MHz UMTS-like exposure. *Bioelectromagnetics.* 26(4):243-250, 2005.

In recent years several studies regarding possible effects of radio frequency (RF) electromagnetic fields (EMFs) on cognitive brain function were reported. In many of these studies on awake humans the working tasks were presented visually to the test subjects, e.g., on a computer screen. Therefore, the question of where in the chain of visual perception, brain processing and response a possible effect could be induced seems to be of interest. In this study, possible effects of exposure to a generic 1.97 GHz UMTS-like signal on human visual perception were investigated in a double blinded,

crossover study including 58 healthy volunteer subjects (29 male, 29 female), aged 29 +/- 5.1 years (mean +/- SD). Each test subject underwent a battery of four different clinical tests three times (two different exposure levels and sham exposure) to assess selected parameters of visual perception. The generic signals applied to the subjects' head represented the RF emissions of an UMTS mobile phone under constant receiving conditions and the under condition of strongly varying transmit power, i.e., the signal envelope contained low frequency components. In the high exposure condition the resulting average exposure of the test subjects in the cortex of the left temporal lobe of the brain was 0.63 W/kg (1 g averaged SAR) and 0.37 W/kg (10 g averaged SAR). Low exposure condition was one tenth of high exposure and sham was at least 50 dB (corresponding to a factor of 100 000) below low exposure. Statistical evaluation of the obtained test results revealed no statistically significant differences in the investigated parameters of visual perception between the exposure conditions and sham exposure.

Schoemaker MJ, Swerdlow AJ, Ahlbom A, Auvinen A, Blaasaas KG, Cardis E, Collatz Christensen H, Feychting M, Hepworth SJ, Johansen C, Klæboe L, Lönn S, McKinney PA, Muir K, Raitanen J, Salminen T, Thomsen J, Tynes T. Mobile phone use and risk of acoustic neuroma: results of the Interphone case-control study in five North European countries. *British Journal of Cancer* (advance online publication 30 August 2005; doi:10.1038/sj.bjc.6602764)

There is public concern that use of mobile phones could increase the risk of brain tumours. If such an effect exists, acoustic neuroma would be of particular concern because of the proximity of the acoustic nerve to the handset. We conducted, to a shared protocol, six population-based case-control studies in four Nordic countries and the UK to assess the risk of acoustic neuroma in relation to mobile phone use. Data were collected by personal interview from 678 cases of acoustic neuroma and 3553 controls. The risk of acoustic neuroma in relation to regular mobile phone use in the pooled data set was not raised (odds ratio (OR)=0.9, 95% confidence interval (CI): 0.7-1.1). There was no association of risk with duration of use, lifetime cumulative hours of use or number of calls, for phone use overall or for analogue or digital phones separately. Risk of a tumour on the same side of the head as reported phone use was raised for use for 10 years or longer (OR=1.8, 95% CI: 1.1-3.1). The study suggests that there is no substantial risk of acoustic neuroma in the first decade after starting mobile phone use. However, an increase in risk after longer term use or after a longer lag period could not be ruled out.

Schoemaker MJ, Swerdlow AJ. Risk of Pituitary Tumors in Cellular Phone Users: A Case-Control Study. *Epidemiology*. 2009 Mar 9. [Epub ahead of print]

BACKGROUND:: There is public concern and scientific interest regarding a potential effect of cellular phone use on the risk of developing intracranial tumors. Tumors of the pituitary gland have barely been investigated in this context, but are of interest because of their intracranial location. **METHODS::** We conducted a population-based case-control study between 2001 and 2005 of the risk of developing pituitary tumors in relation to cellular phone use in Southeast England, with 291 cases and 630 controls. Detailed information on cellular phone use was collected by personal interview. **RESULTS::** Tumor risk was not associated with cellular phone use overall (adjusted odds ratio = 0.9, 95% confidence interval = 0.7-1.3), and was not appreciably increased 10 or more years after first use (1.0; 0.5-1.9), or after 10 or more years of cumulative use (1.1; 0.5-2.4). Odds ratios were 1.2 (0.7-1.9) for users in the highest quartile of cumulative number of calls and 1.1 (0.7-1.7) in the highest quartile of hours of use. Separate analyses of analog and digital phone use showed no associations with tumor risk. **CONCLUSIONS::** We found no evidence that the risk of developing pituitary tumors is associated with cellular phone use for the induction time periods and intensities of use observed.

Schuz J, Bohler E, Berg G, Schlehofer B, Hettinger I, Schläefer K, Wahrendorf J, Kunna-Grass K, Blettner M. Cellular Phones, Cordless Phones, and the Risks of Glioma and Meningioma (Interphone Study Group, Germany). *Am J Epidemiol*. 2006 Jan 27; [Epub ahead of print]

The widespread use of cellular telephones has generated concern about possible adverse health effects, particularly brain tumors. In this population-based case-control study carried out in three regions of Germany, all incident cases of glioma and meningioma among patients aged 30-69 years were ascertained during 2000-2003. Controls matched on age, gender,

and region were randomly drawn from population registries. In total, 366 glioma cases, 381 meningioma cases, and 1,494 controls were interviewed. Overall use of a cellular phone was not associated with brain tumor risk; the respective odds ratios were 0.98 (95% confidence interval (CI): 0.74, 1.29) for glioma and 0.84 (95% CI: 0.62, 1.13) for meningioma. Among persons who had used cellular phones for 10 or more years, increased risk was found for glioma (odds ratio = 2.20, 95% CI: 0.94, 5.11) but not for meningioma (odds ratio = 1.09, 95% CI: 0.35, 3.37). No excess of temporal glioma ($p = 0.41$) or meningioma ($p = 0.43$) was observed in cellular phone users as compared with nonusers. Cordless phone use was not related to either glioma risk or meningioma risk. In conclusion, no overall increased risk of glioma or meningioma was observed among these cellular phone users; however, for long-term cellular phone users, results need to be confirmed before firm conclusions can be drawn.

Schuz J, Bohler E, Schlehofer B, Berg G, Schlaefer K, Hettinger I, Kunna-Grass K, Wahrendorf J, Blettner M. Radiofrequency Electromagnetic Fields Emitted from Base Stations of DECT Cordless Phones and the Risk of Glioma and Meningioma (Interphone Study Group, Germany). *Radiat Res.* 166(1):116-119, 2006.

The objective of this study was to test the hypothesis that exposure to continuous low-level radiofrequency electromagnetic fields (RF EMFs) increases the risk of glioma and meningioma. Participants in a population-based case-control study in Germany on the risk of brain tumors in relation to cellular phone use were 747 incident brain tumor cases between the ages of 30 and 69 years and 1494 matched controls. The exposure measure of this analysis was the location of a base station of a DECT (Digital Enhanced Cordless Telecommunications) cordless phone close to the bed, which was used as a proxy for continuous low-level exposure to RF EMFs during the night. Estimated odds ratios were 0.82 (95% confidence interval: 0.29-2.33) for glioma and 0.83 (0.29-2.36) for meningioma. There was also no increasing risk observed with duration of exposure to DECT cordless phone base stations. Although the study was limited due to the small number of exposed subjects, it is still a first indication that residential low-level exposure to RF EMFs may not pose a higher risk of brain tumors.

Schüz J, Jacobsen R, Olsen JH, Boice, JD Jr, McLaughlin JK, Johansen C. Cellular Telephone Use and Cancer Risk: Update of a Nationwide Danish Cohort. *J. Natl Cancer Inst* 98:1707-1713, 2006.

Background: The widespread use of cellular telephones has heightened concerns about possible adverse health effects. The objective of this study was to investigate cancer risk among Danish cellular telephone users who were followed for up to 21 years. *Methods:* This study is an extended follow-up of a large nationwide cohort of 420 095 persons whose first cellular telephone subscription was between 1982 and 1995 and who were followed through 2002 for cancer incidence. Standardized incidence ratios (SIRs) were calculated by dividing the number of observed cancer cases in the cohort by the number expected in the Danish population. *Results:* A total of 14 249 cancers were observed (SIR = 0.95; 95% confidence interval [CI] = 0.93 to 0.97) for men and women combined. Cellular telephone use was not associated with increased risk for brain tumors (SIR = 0.97), acoustic neuromas (SIR = 0.73), salivary gland tumors (SIR = 0.77), eye tumors (SIR = 0.96), or leukemias (SIR = 1.00). Among long-term subscribers of 10 years or more, cellular telephone use was not associated with increased risk for brain tumors (SIR = 0.66, 95% CI = 0.44 to 0.95), and there was no trend with time since first subscription. The risk for smoking-related cancers was decreased among men (SIR = 0.88, 95% CI = 0.86 to 0.91) but increased among women (SIR = 1.11, 95% CI = 1.02 to 1.21). Additional data on income and smoking prevalence, primarily among men, indicated that cellular telephone users who started subscriptions in the mid-1980s appeared to have a higher income and to smoke less than the general population. *Conclusions:* We found no evidence for an association between tumor risk and cellular telephone use among either short-term or long-term users. Moreover, the narrow confidence intervals provide evidence that any large association of risk of cancer and cellular telephone use can be excluded.

Schwarz C, Kratochvil E, Pilger A, Kuster N, Adlkofer F, Rüdiger HW. Radiofrequency electromagnetic fields (UMTS, 1,950 MHz) induce genotoxic effects in vitro in human fibroblasts but not in lymphocytes. *Int Arch Occup Environ Health.* 81(6):755-767, 2008.

OBJECTIVE: Universal Mobile Telecommunication System (UMTS) was recently introduced as the third generation mobile communication standard in Europe. This was done without any information on biological effects and genotoxic properties of these particular high-frequency electromagnetic fields. This is disconcerting, because genotoxic effects of the second generation standard Global System for Mobile Communication have been reported after exposure of human cells in vitro. **METHODS:** Human cultured fibroblasts of three different donors and three different short-term human lymphocyte cultures were exposed to 1,950 MHz UMTS below the specific absorption rate (SAR) safety limit of 2 W/kg.

The alkaline comet assay and the micronucleus assay were used to ascertain dose and time-dependent genotoxic effects. Five hundred cells per slide were visually evaluated in the comet assay and comet tail factor (CTF) was calculated. In the micronucleus assay 1,000 binucleated cells were evaluated per assay. The origin of the micronuclei was determined by fluorescence labeled anticentromere antibodies. All evaluations were performed under blinded conditions. **RESULTS:** UMTS exposure increased the CTF and induced centromere-negative micronuclei (MN) in human cultured fibroblasts in a dose and time-dependent way. Incubation for 24 h at a SAR of 0.05 W/kg generated a statistically significant rise in both CTF and MN ($P = 0.02$). At a SAR of 0.1 W/kg the CTF was significantly increased after 8 h of incubation ($P = 0.02$), the number of MN after 12 h ($P = 0.02$). No UMTS effect was obtained with lymphocytes, either unstimulated or stimulated with Phytohemagglutinin. **CONCLUSION:** UMTS exposure may cause genetic alterations in some but not in all human cells in vitro.

Shallom JM, Di Carlo AL, Ko D, Penafiel LM, Nakai A, Litovitz TA.

Microwave exposure induces Hsp70 and confers protection against hypoxia in chick embryos. *J Cell Biochem* 86(3):490-496, 2002.

To determine if microwave exposure could elicit a biological effect in the absence of thermal stress, studies were designed in which chick embryos were exposed to athermal microwave radiation (915 MHz) to look for induction of Hsp70, a protein produced during times of cellular stress that aids in the protection of cellular components. Levels of Hsp70 were found to increase within 2 h, with maximum expression (approximately 30% higher than controls) typically occurring by 3 h from the start of exposure. Other embryos were exposed to microwave radiation prior to being subjected to hypoxic stress, and were found to have significantly higher survival ($P < 0.05$) following re-oxygenation than non-exposed controls. The results of these studies indicate that not only can athermal microwave exposures activate the stress protein response pathway; they can also enhance survivability following exposure to a subsequent, potentially lethal stress. From a public health standpoint, it is important that more studies be performed to determine if repeated exposures, a condition likely to be found in cell phone use, are still beneficial.

Shirai T, Kawabe M, Ichihara T, Fujiwara O, Taki M, Watanabe SI, Wake K, Yamanaka Y, Imaida K, Asamoto M, Tamano S. Chronic exposure to a 1.439 GHz electromagnetic field used for cellular phones does not promote N-ethylnitrosourea induced central nervous system tumors in F344 rats. *Bioelectromagnetics* 26:59-68, 2005.

The present study was designed to evaluate whether a 2 year exposure to an electromagnetic field (EMF) equivalent to that generated by cellular phones can accelerate tumor development in the central nervous system (CNS) of rats. Brain tumorigenesis was initiated by an intrauterine exposure to N-ethylnitrosourea (ENU) on gestational day 18. A total of 500 pups were divided into five groups, each composed of 50 males and 50 females: Group 1, untreated control; Group 2, ENU alone; Groups 3-5, ENU + EMF (sham exposure and 2 exposure levels). A 1.439 GHz time division multiple access (TDMA) signal for the Personal Digital Cellular (PDC), Japanese standard cellular system was used for the exposure of the rat head starting from 5 weeks of age, 90 min a day, 5 days a week, for 104 weeks. Brain average specific absorption rate (SAR) was 0.67 and 2.0 W/kg for low and high exposures, respectively: whole body average SAR was less than 0.4 W/kg. There were no inter-group differences in body weights, food consumption, and survival rates. No increase in the incidences or numbers per group of brain and/or spinal cord tumors, either in the males or females, was detected in the EMF exposed groups. In addition, no clear changes in tumor types were evident. Thus, under the present experimental conditions, 1.439 GHz EMF exposure to the heads of rats for a 2 year period was not demonstrated to accelerate or affect ENU initiated brain tumorigenesis.

Shirai T, Ichihara T, Wake K, Watanabe SI, Yamanaka Y, Kawabe M, Taki M, Fujiwara O, Wang J, Takahashi S, Tamano S. Lack of promoting effects of chronic exposure to 1.95-GHz W-CDMA signals for IMT-2000 cellular system on development of N-ethylnitrosourea-induced central nervous system tumors in F344 rats. *Bioelectromagnetics*. 2007 May 21; [Epub ahead of print]

The present study was performed to evaluate effects of a 2-year exposure to an electromagnetic near-field (EMF) equivalent to that generated by cellular phones on tumor development in the central nervous system (CNS) of rats. For this purpose, pregnant F344 rats were given a single administration of N-ethylnitrosourea (ENU) on gestational day 18. A total of 500 pups were divided into five groups, each composed of 50 males and 50 females: Group 1, untreated controls; Group 2, ENU alone; Groups 3 to 5, ENU + EMF (sham exposure and two exposure levels). A 1.95-GHz wide-band code

division multiple access (W-CDMA) signal, which is a feature of the International Mobile Telecommunication 2000 (IMT-2000) cellular system was employed for exposure of the rat head starting from 5 weeks of age, 90 min a day, 5 days a week, for 104 weeks. Brain average specific absorption rates (SARs) were designed to be .67 and 2.0 W/kg for low and high exposures, respectively. The incidence and numbers of brain tumors in female rats exposed to 1.95-GHz W-CDMA signals showed tendencies to increase but without statistical significance. Overall, no significant increase in incidences or numbers, either in the males or females, was detected in the EMF-exposed groups. In addition, no clear changes in tumor types in the brain were evident. Thus, under the present experimental conditions, exposure of heads of rats to 1.95-GHz W-CDMA signals for IMT-2000 for a 2-year period was not demonstrated to accelerate or otherwise affect ENU-initiated brain tumorigenesis.

Schoemaker MJ, Swerdlow AJ. Risk of Pituitary Tumors in Cellular Phone Users: A Case-Control Study. Epidemiology. 2009 Mar 9. [Epub ahead of print]

BACKGROUND:: There is public concern and scientific interest regarding a potential effect of cellular phone use on the risk of developing intracranial tumors. Tumors of the pituitary gland have barely been investigated in this context, but are of interest because of their intracranial location. **METHODS::** We conducted a population-based case-control study between 2001 and 2005 of the risk of developing pituitary tumors in relation to cellular phone use in Southeast England, with 291 cases and 630 controls. Detailed information on cellular phone use was collected by personal interview.

RESULTS:: Tumor risk was not associated with cellular phone use overall (adjusted odds ratio = 0.9, 95% confidence interval = 0.7-1.3), and was not appreciably increased 10 or more years after first use (1.0; 0.5-1.9), or after 10 or more years of cumulative use (1.1; 0.5-2.4). Odds ratios were 1.2 (0.7-1.9) for users in the highest quartile of cumulative number of calls and 1.1 (0.7-1.7) in the highest quartile of hours of use. Separate analyses of analog and digital phone use showed no associations with tumor risk. **CONCLUSIONS::** We found no evidence that the risk of developing pituitary tumors is associated with cellular phone use for the induction time periods and intensities of use observed

Sienkiewicz ZJ, Blackwell RP, Haylock RG, Saunders RD, Cobb BL, Low-level exposure to pulsed 900 MHz microwave radiation does not cause deficits in the performance of a spatial learning task in mice. Bioelectromagnetics 21(3):151-158, 2000.

There is some concern that short-term memory loss or other cognitive effects may be associated with the use of mobile cellular telephones. In this experiment, the effect of repeated, acute exposure to a low intensity 900 MHz radiofrequency (RF) field pulsed at 217 Hz was explored using an appetitively-motivated spatial learning and working memory task. Adult male C57BL/6J mice were exposed under far field conditions in a GTEM cell for 45 min each day for 10 days at an average whole-body specific energy absorption rate (SAR) of 0.05 W/kg. Their performance in an 8-arm radial maze was compared to that of sham-exposed control animals. All behavioral assessments were performed without handlers having knowledge of the exposure status of the animals. Animals were tested in the maze immediately following exposure or after a delay of 15 or 30 min. No significant field-dependent effects on performance were observed in choice accuracy or in total times to complete the task across the experiment. These results suggest that exposure to RF radiation simulating a digital wireless telephone (GSM) signal under the conditions of this experiment does not affect the acquisition of the learned response. Further studies are planned to explore the effects of other SARs on learned behavior.

Sievert U, Eggert S, Pau HW. Can mobile phone emissions affect auditory functions of cochlea or brain stem? Otolaryngol Head Neck Surg. 132(3):451-455, 2005.

Problems addressed Despite their abundant spread, mobile phones are suspected by a major share of the population to cause adverse effects on health and welfare. The ear as the sense organ next to the individual device has rarely been investigated for short-term effects in this regard. In a previous article, we could not prove any impact on the vestibular part of the inner ear. Our present examinations are concerned with the question whether mobile phone emissions could affect cochlear or auditory brain stem functions. Methods and measures In 12 healthy test persons with normal hearing, auditory brain stem reflexes recordings were performed before, during, and after exposure to electromagnetic emissions by standardized mobile phone devices. Two modes of electromagnetic emissions fields were administered: pulsed and continuous. For acoustic stimulation simultaneous to field exposure, special "plug-in" earphones had to be used. Results No impact on auditory brain stem reflexes recordings in terms of absolute and interpeak latencies could be found. Clinical significance Together with the results of a previous article concerned with the vestibular part of the inner ear, we can state

that there are no adverse effects of mobile phone emissions on the ear function, at least on a short-term range. Of course, any long-term effects cannot be excluded by our study.

Simko M, Hartwig C, Lantow M, Lupke M, Mattsson MO, Rahman Q, Rollwitz J. Hsp70 expression and free radical release after exposure to non-thermal radio-frequency electromagnetic fields and ultrafine particles in human Mono Mac 6 cells. *Toxicol Lett.* 161(1):73-82, 2006.

The contemporary urban environment has become increasingly complex in its composition, leading to discussions regarding possible novel health effects. Two factors that recently have received considerable attention are ultrafine particles (UFP; <0.1µm) produced by combustion processes and emissions from wireless communication devices like mobile phones that emit in the radio-frequency (RF) part of the spectrum. Several studies have shown biological effects of both these exposures in various cell systems. Here we investigate if exposure to UFP (12-14nm, 100µg/ml) and RF-electromagnetic fields (EMF; 2W/kg specific absorption rate (SAR); continuous wave (CW) or modulated (217Hz or GSM-nonDTX)), alone or in combination influences levels of the superoxide radical anion or the stress protein heat-shock protein (Hsp70) in the human monocyte cell line Mono Mac 6. Heat treatment (42-43 degrees C, 1h) was used as positive control for both stress reaction and for heat development in the RF exposure setup. Our results clearly show that Mono Mac 6 cells are capable to internalise UFP, and that this phagocytic activity is connected to an increased release of free radicals. This increase (40-45% above negative control) is stronger than the effect of heat treatment. On the other hand, none of the employed RF exposures showed any effects on free radical levels. Co-exposure of RF and UFP did not potentiate the UFP effect either. Our investigations showed a significantly increased Hsp70 expression level by heat treatment in a time-dependent manner, whereas UFP, RF, or UFP+RF were without any effect. Therefore, we conclude that in the investigated Mono Mac 6 cells, RF exposure alone or in combination with UFP cannot influence stress-related responses.

Simsek V, Sahin H, Akay AF, Kaya H, Bircan MK. The effects of cellular telephone use on serum PSA levels in men. *Int Urol Nephrol.* 35(2):193-196, 2003.

BACKGROUND: The increasing use of cellular telephones is known to have harmful effects on human health. The aim of this prospective study was to determine whether cellular telephone use affected serum PSA levels in men. **METHODS:** Participants included 20 men with ages ranging from 22 to 65 years who had never previously used cellular telephones. Blood samples were taken prior to and 30 days after the beginning of cellular telephone use. Serum was separated from the blood samples and stored in a deep freezer until the end of the study, at which time serum free and total PSA levels were determined by tandem radioimmunoassay. The results were statistically analyzed by the Wilcoxon Paired Signed Rank Test. **RESULTS:** Average free and total PSA values were 2.070 ng/ml and 0.500 ng/ml before the study, and 2.0 ng/ml and 0.505 ng/ml at the end of the study, respectively. No significant difference was determined between the initial and final values ($p > 0.05$). **CONCLUSIONS:** The results indicate that cellular telephone use does not significantly affect PSA values in the short term. Nevertheless, we think that there is a need for longer-term studies on this subject.

Singh B, Bate LA, Responses of pulmonary intravascular macrophages to 915-MHz microwave radiation: ultrastructural and cytochemical study. *Anat Rec* 246(3):343-355, 1996.

BACKGROUND: Microwave (MW) radiation is being increasingly used as a source of heat supplementation during early postnatal development of pigs. Although MW radiation does not cause deleterious physiological effects, no specific information exists regarding its impact on immune cells such as macrophages. Pulmonary intravascular macrophages (PIMs) are emerging as important inflammatory cells due to their endocytic and secretory potential. An in vivo study was conducted to evaluate the effects of infrared, and low and high power MW radiation on the PIMs of pigs. **METHODS:** Pigs were exposed to infrared (IR), low MW (LMW; 6.1mW cm⁻²), and high MW (HMW; 11.4mW cm⁻²) radiation at 915 MHz (n = 2 for each treatment) for 24 hr. The controls (n = 2) were exposed to natural light for the same period of time. Lung tissues were processed for ultrastructural examination and acid phosphatase (AcPase) cytochemistry. In addition, rough endoplasmic reticulum (RER) as a fraction of cytosol of the PIMs was counted. **RESULTS:**

Ultrastructural and numerical data suggested enhanced secretory activity in the PIMs of LMW-treated pigs as indicated by the increased RER:cytoplasm ratio, prominent Golgi complex profiles, and accumulation of secretory vesicles in conjunction with microtubules as compared with the control, IR, and HMW-exposed pigs. High MW treatment induced some damage to pulmonary interstitium as deduced from the presence of extracellular AcPase precipitates and disrupted collagen matrix. Intracellular globules were noticed in the PIMs of IR and LMW-treated pigs but not in the control and HMW-radiated animals. **CONCLUSIONS:** Elaboration of structural signs of secretory activity in the PIMs by LMW radiation in the absence of pulmonary pathological changes indicates its potential for cell activation in addition to the already established role of LMW in heat supplementation. This activation could be due to either increased core body temperature or initiation of intracellular signaling by the LMW radiation. This study also shows that the HMW radiation is capable of inducing pathology in the form of changes in the pulmonary interstitial matrix and may not be a good source of supplementary heat.

Smith P, Kuster N, Ebert S, Chevalier H.J. GSM and DCS Wireless Communication Signals: Combined Chronic Toxicity/Carcinogenicity Study in the Wistar Rat. Radiat Res. 168(4):480-492, 2007.

.A total of 1170 rats comprised of 65 male and 65 female Han Wistar rats per group were exposed for 2 h/day, 5 days/week for up to 104 weeks to GSM or DCS wireless communication signals at three nominal SARs of 0.44, 1.33 and 4.0 W/kg. A preliminary study confirmed that the highest exposure level was below that which was capable of causing a measurable increase in the core temperature of the rat. Additional groups for each modulation were sham exposed, and there was also an unrestrained, unexposed (cage) control group. Fifteen male and 15 female rats per group were killed after 52 weeks. From the remaining 50 male and 50 female rats per group, surviving animals were killed after 104 weeks. Evaluations during the study included mortality rate, clinical signs, recording of palpable masses, body weight, food consumption, ophthalmoscopic examination, and clinical pathological investigations. Terminal investigations included organ weight measurement and macroscopic and microscopic pathology examinations. There was no adverse response to the wireless communication signals. In particular, there were no significant differences in the incidence of primary neoplasms, the number of rats with more than one primary neoplasm, the multiplicity and latency of neoplasms, the number of rats with metastases, and the number of benign and malignant neoplasms between the rats exposed to wireless communication signals and rats that were sham exposed.

Smythe JW, Costall B. Mobile phone use facilitates memory in male, but not female, subjects. *Neuroreport* 14(2):243-246, 2003.

In the present study we report on the effects of mobile phone exposure on short- and long-term memory in male and female subjects. Subjects were university undergraduate students, and consisted of right-handed, males (= 33) and females (= 29). Individuals were randomly assigned to one of three experimental conditions: no phone exposure; inactive phone exposure; and active phone exposure. They were provided with a series of words to learn, structured in a two-dimensional shape, and given 3 min to memorise the words. After a 12 min distraction task, they were then asked to draw the shape (spatial) and place the correct words (semantic) into the appropriate boxes. One week later the same subjects were brought back to again redraw the shape and words. Error scores were determined and analysed by non-parametric techniques. The results show that males exposed to an active phone made fewer spatial errors than those exposed to an active phone condition, while females were largely unaffected. These results further indicate that mobile phone exposure has functional consequences for human subjects, and these effects appear to be sex-dependent.

Soderqvist F, Carlberg M, Hardell L. Use of wireless telephones and self-reported health symptoms: a population-based study among Swedish adolescents aged 15-19 years. Environ Health. 2008 May 21;7(1):18. [Epub ahead of print]

ABSTRACT: BACKGROUND: Despite the last years of rapid increase in use of wireless phones little data on the use of these devices has been systematically assessed among young persons. The aim of this descriptive cross-sectional study was to assess use of wireless phones and to study such use in relation to explanatory factors and self-reported health symptoms. **METHODS:** A postal questionnaire comprising 8 pages of 27 questions with 75 items in total was sent to 2000 Swedish adolescents aged 15-19 years and selected from the population registry using a stratified sampling scheme. **RESULTS:** The questionnaire was answered by 63.5 % of the study subjects. Most participants reported access to a

mobile phone (99.6%) and use increased with age; 55.6% of the 15-year-olds and 82.2% of the 19-year-olds were regular users. Girls generally reported more frequent use than boys. Use of wired hands-free equipment 'anytime' was reported by 17.4%. Cordless phones were used by 81.9%, and 67.3% were regular users. Watching TV increased the odds ratio for use of wireless phones, adjusted for age and gender. Some of the most frequently reported health complaints were tiredness, stress, headache, anxiety, concentration difficulties and sleep disturbances. Regular users of wireless phones had health symptoms more often and reported poorer perceived health than less frequent users. **CONCLUSIONS:** Almost all adolescence in this study used a wireless phone, girls more than boys. The most frequent use was seen among the older adolescents and those who watched TV extensively. The study further showed that perceived health and certain health symptoms seemed to be related to the use of wireless phones. However, this part of the investigation was explorative and should therefore be interpreted with caution since bias and chance findings due to multiple testing might have influenced the results. Potentially this study will stimulate more sophisticated studies that may also investigate directions of associations and whether, or to what degree, any mediation factors are involved.

Söderqvist F, Carlberg M, Hardell L. Use of wireless telephones and serum S100B levels: A descriptive cross-sectional study among healthy Swedish adults aged 18-65 years. *Sci Total Environ.* 407(2):798-805, 2009

BACKGROUND: Since the late 1970s, experimental animal studies have been carried out on the possible effects of low-intensive radiofrequency fields on the blood-brain barrier (BBB), but no epidemiological study has been published to date. **OBJECTIVE:** Using serum S100B as a putative marker of BBB dysfunction we performed a descriptive cross-sectional study to investigate whether protein levels were higher among frequent than non-frequent users of mobile and cordless desktop phones. **METHOD:** One thousand subjects, 500 of each sex aged 18-65 years, were randomly recruited using the population registry. Data on wireless phone use were assessed by a postal questionnaire and blood samples were analyzed for S100B. **RESULTS:** The response rate was 31.4%. The results from logistic and linear regression analyses were statistically insignificant, with one exception: the linear regression analysis of latency for UMTS use, which after stratifying on gender remained significant only for men ($p = 0.01$; $n = 31$). A low p -value (0.052) was obtained for use of cordless phone ($n = 98$) prior to giving the blood samples indicating a weak negative association. Total use of mobile and cordless phones over time yielded odds ratio (OR) 0.8 and 95% confidence interval (CI) 0.3-2.0 and use on the same day as giving blood yielded OR=1.1, CI=0.4-2.8. **CONCLUSIONS:** This study failed to show that long- or short-term use of wireless telephones was associated with elevated levels of serum S100B as a marker of BBB integrity. The finding regarding latency of UMTS use may be interesting but it is based on small numbers. Generally, S100B levels were low and to determine whether this association - if causal - is clinically relevant, larger studies with sufficient follow-up are needed.

Soderqvist F, Carlberg M, Hardell L. Mobile and cordless telephones, serum transthyretin and the blood-cerebrospinal fluid barrier: a cross-sectional study. *Environ Health.* 8(1):19, 2009.

ABSTRACT: BACKGROUND: Whether low-intensity radiofrequency radiation damages the blood-brain barrier has long been debated, but little or no consideration has been given to the blood-cerebrospinal fluid barrier. In this cross-sectional study we tested whether long-term and/or short-term use of wireless telephones was associated with changes in the serum transthyretin level, indicating altered transthyretin concentration in the cerebrospinal fluid, possibly reflecting an effect of radiation. **METHODS:** One thousand subjects, 500 of each sex aged 18-65 years, were randomly recruited using the population registry. Data on wireless telephone use were assessed by a postal questionnaire and blood samples were analyzed for serum transthyretin concentrations determined by standard immunonephelometric techniques on a BN Prospec(R) instrument. **RESULTS:** The response rate was 31.4%. Logistic regression of dichotomized TTR serum levels with a cut-point of 0.31 g/l on wireless telephone use yielded increased odds ratios that were statistically not significant. Linear regression of time since first use overall and on the day that blood was withdrawn gave different results for males and females: for men significantly higher serum concentrations of TTR were seen the longer an analogue telephone or a mobile and cordless desktop telephone combined had been used, and in contrast, significantly lower serum levels were seen the longer an UMTS telephone had been used. Adjustment for fractions of use of the different telephone types did not modify the effect for cumulative use or years since first use for mobile telephone and DECT, combined. For women, linear regression gave a significant association for short-term use of mobile and cordless telephones combined, indicating that the sooner blood was withdrawn after the most recent telephone call, the higher the expected transthyretin concentration. **CONCLUSIONS:** In this hypothesis-generating descriptive study time since first use of mobile telephones and DECT combined was significantly associated with higher TTR levels regardless of how much each telephone type had been used. Regarding short-term use, significantly higher TTR concentrations were seen in women the sooner blood was withdrawn after the most recent telephone call on that day.

Sokolovic D, Djindjic B, Nikolic J, Bjelakovic G, Pavlovic D, Kocic G, Krstic D, Cvetkovic T, Pavlovic V. Melatonin Reduces Oxidative Stress Induced by Chronic Exposure of Microwave Radiation from Mobile Phones in Rat Brain. J Radiat Res (Tokyo). 2008 Sep 29. [Epub ahead of print]

Purpose: The aim of the study was to evaluate the intensity of oxidative stress in the brain of animals chronically exposed to mobile phones and potential protective effects of melatonin in reducing oxidative stress and brain injury. Materials and methods: Experiments were performed on Wistar rats exposed to microwave radiation during 20, 40 and 60 days. Four groups were formed: I group (control)- animals treated by saline, intraperitoneally (i.p.) applied daily during follow up, II group (Mel)- rats treated daily with melatonin (2 mg kg⁻¹ body weight i.p.), III group (MWs)- microwave exposed rats, IV group (MWs + Mel)- MWs exposed rats treated with melatonin (2 mg kg⁻¹ body weight i.p.). The microwave radiation was produced by a mobile test phone (SAR = 0.043-0.135 W/kg). Results: A significant increase in the brain tissue malondialdehyde (MDA) and carbonyl group concentration was registered during exposure. Decreased activity of catalase (CAT) and increased activity of xanthine oxidase (XO) remained after 40 and 60 days of exposure to mobile phones. Melatonin treatment significantly prevented the increase in the MDA content and XO activity in the brain tissue after 40 days of exposure while it was unable to prevent the decrease of CAT activity and increase of carbonyl group contents. Conclusion: We demonstrated two important findings; that mobile phones caused oxidative damage biochemically by increasing the levels of MDA, carbonyl groups, XO activity and decreasing CAT activity; and that treatment with the melatonin significantly prevented oxidative damage in the brain.

Sommer AM, Streckert J, Bitz AK, Hansen VW, Lerchl A. No effects of GSM-modulated 900 MHz electromagnetic fields on survival rate and spontaneous development of lymphoma in female AKR/J mice. BMC Cancer. 2004 Nov 11;4(1):77 [Epub ahead of print]

BACKGROUND: There are several reports that indicate that non-thermal electromagnetic radiation such as from mobile phones and base stations may promote cancer. Therefore, it was investigated experimentally, whether 900 MHz electromagnetic field exposure influences lymphoma development in a mouse strain that is genetically predisposed to this disease. The AKR/J mice genome carries the AK-virus, which leads within one year to spontaneous development of thymic lymphoblastic lymphoma. METHODS: 48 groups of 6-7 unrestrained female mice were sham-exposed or exposed (each n = 160 animals) to GSM like 900 MHz electromagnetic fields for 24 hours per day, 7 days per week, at an average whole body specific absorption rates (SAR) values of 0.4 W/Kg. Animals were visually checked daily and were weighed and palpated weekly. Starting with an age of 6 months, blood samples were taken monthly from the tail. Animals with signs of disease or with an age of about 42 weeks were sacrificed and a gross necropsy was performed. RESULTS: There was no effect of electromagnetic field exposure on body weight gain or survival rate, and lymphoma incidence did not differ between exposed and sham-exposed animals. CONCLUSION: These data do not support the hypothesis that exposure to 900 MHz electromagnetic fields is a significant risk factor for developing lymphoma in a genetically predisposed species, even at a relatively high exposure level.

Sommer AM, Bitz AK, Streckert J, Hansen VW, Lerchl A. Lymphoma development in mice chronically exposed to UMTS-modulated radiofrequency electromagnetic fields. Radiat Res. 168(1):72-80, 2007.

There are public concerns regarding possible carcinogenic or cancer-promoting effects of electromagnetic fields (EMFs) from mobile phones and base stations. The objective of the present study was to investigate whether chronic exposure to EMFs of the UMTS (Universal Mobile Telecommunication System) influences the development of lymphoma in a lymphoma animal model, the AKR/J mouse. Unrestrained mice were chronically sham-exposed (n = 160) or exposed (n = 160) in identical exposure systems (radial waveguides) to a generic UMTS test signal (24 h per day, 7 days per week, 0.4 W/kg SAR). Additionally, 30 animals were kept as cage controls. Animals were checked visually each day and were weighed and palpated weekly to detect swollen lymph nodes. Starting at the age of 6 months, blood samples were taken from the tail every 2 weeks to perform differential leukocyte counts and to measure the hematocrit. Visibly diseased animals or those older than 43 weeks were killed humanely, and tissue slices were examined for metastatic infiltrations and lymphoma type. The study was performed in a blinded way. Cage control animals had a significantly lower growth

rate than those kept in the radial waveguides. The number of ill animals, the mean survival time, and the severity code of the disease did not differ between the experimental groups. Therefore, the data show no negative effects from exposure and corroborate earlier findings in AKR/J mice exposed to GSM EMF (Sommer et al., BMC Cancer 4, 77-90, 2004).

Sommer, A. M., Grote, K., Reinhardt, T., Streckert, J., Hansen, V. and Lerchl, A. Effects of Radiofrequency Electromagnetic Fields (UMTS) on Reproduction and Development of Mice: A Multi-generation Study. Radiat. Res. 171: 89-95, 2009.

Male and female mice (C57BL) were chronically exposed (life-long, 24 h/day) to mobile phone communication electromagnetic fields at approximately 1966 MHz (UMTS). Their development and fertility were monitored over four generations by investigating histological, physiological, reproductive and behavioral functions. The mean whole-body SARs, calculated for adult animals at the time of mating, were 0 (sham), 0.08, 0.4 and 1.3 W/kg. Power densities were kept constant for each group (0, 1.35, 6.8 and 22 W/m²), resulting in varying SARs due to the different numbers of adults and pups over the course of the experiment. The experiment was done in a blind fashion. The results show no harmful effects of exposure on the fertility and development of the animals. The number and the development of pups were not affected by exposure. Some data, albeit without a clear dose-response relationship, indicate effects of exposure on food consumption that is in accordance with some data published previously. In summary, the results of this study do not indicate harmful effects of long-term exposure of mice to UMTS over several generations.

Stagg RB, Thomas WJ, Jones RA, Adey WR, DNA synthesis and cell proliferation in C6 glioma and primary glial cells exposed to a 836.55 MHz modulated radiofrequency field. Bioelectromagnetics 18(3):230-236, 1997.

We have tested the hypothesis that modulated radiofrequency (RF) fields may act as a tumor-promoting agent by altering DNA synthesis, leading to increased cell proliferation. In vitro tissue cultures of transformed and normal rat glial cells were exposed to an 836.55 MHz, packet-modulated RF field at three power densities: 0.09, 0.9, and 9 mW/cm², resulting in specific absorption rates (SARs) ranging from 0.15 to 59 μ W/g. TEM-mode transmission-line cells were powered by a prototype time-domain multiple-access (TDMA) transmitter that conforms to the North American digital cellular telephone standard. One sham and one energized TEM cell were placed in standard incubators maintained at 37 degrees C and 5% CO₂. DNA synthesis experiments at **0.59-59 μ W/g SAR** were performed on log-phase and serum-starved semiquiescent cultures after 24 h exposure. Cell growth at 0.15-15 μ W/g SAR was determined by cell counts of log-phase cultures on days 0, 1, 5, 7, 9, 12, and 14 of a 2 week protocol. Results from the DNA synthesis assays differed for the two cell types. Sham-exposed and RF-exposed cultures of primary rat glial cells showed no significant differences for either log-phase or serum-starved condition. ***C6 glioma cells exposed to RF at 5.9 μ W/g SAR (0.9 mW/cm²) exhibited small (20-40%) significant increases in 38% of [3H]thymidine incorporation experiments.*** Growth curves of sham and RF-exposed cultures showed no differences in either normal or transformed glial cells at any of the power densities tested. Cell doubling times of C6 glioma cells [sham (21.9 \pm 1.4 h) vs. field (22.7 \pm 3.2 h)] also demonstrated no significant differences that could be attributed to altered DNA synthesis rates. Under these conditions, this modulated RF field did not increase cell proliferation of normal or transformed cultures of glial origin.

Stagg RB, Hawel LH III, Pastorian K, Cain C, Adey WR, Byus CV, Effect of Immobilization and Concurrent Exposure to a Pulse-Modulated Microwave Field on Core Body Temperature, Plasma ACTH and Corticosteroid, and Brain Ornithine Decarboxylase, Fos and Jun mRNA. Radiat Res 155(4):584-592, 2001.

Effect of Immobilization and Concurrent Exposure to a Pulse-Modulated Microwave Field on Core Body Temperature, Plasma ACTH and Corticosteroid, and Brain Ornithine Decarboxylase, Fos and Jun mRNA. Exposure of humans and rodents to radiofrequency (RF) cell phone fields has been reported to alter a number of stress-related parameters. To study this potential relationship in more detail, tube-restrained immobilized Fischer 344 rats were exposed in the near field in a dose-dependent manner to pulse-modulated (11 packets/s) digital cell phone microwave fields at 1.6 GHz in accordance with the Iridium protocol. Core body temperatures, plasma levels of the stress-induced hormones adrenocorticotrophic hormone (ACTH) and corticosterone, and brain levels of ornithine decarboxylase (Odc), Fos and Jun mRNAs were measured as potential markers of stress responses mediated by RF radiation. We tested the effects of the loose-tube immobilization with and without prior conditioning throughout a 2-h period (required for near-field head

exposure to RF fields), on core body temperature, plasma ACTH and corticosteroids. Core body temperature increased transiently (± 0.3 degrees C) during the initial 30 min of loose-tube restraint in conditioned animals. When conditioned/tube-trained animals were followed as a function of time after immobilization, both the ACTH and corticosterone levels were increased by nearly 10-fold. For example, within 2-3 min, ACTH increased to 83.2 ± 31.0 pg/dl, compared to 28.1 ± 7.7 pg/dl for cage controls, reaching a maximum at 15-30 min (254.6 ± 46.8 pg/dl) before returning to near resting levels by 120 min (31.2 ± 10.2 pg/dl). However, when non-tube-trained animals were submitted to loose-tube immobilization, these animals demonstrated significantly higher (3-10-fold greater) hormone levels at 120 min than their tube-trained counterparts (313.5 ± 54.8 compared to 31.2 ± 10.2 pg/dl; corticosterone, 12.2 ± 6.2 μ g/dl compared to 37.1 ± 6.4 μ g/dl). Hormone levels in exposed animals were also compared to those in swim-stressed animals. Swimming stress also resulted in marked elevation in both ACTH and corticosterone levels, which were 10-20 fold higher (541.8 compared to 27.2 - 59.1 pg/dl for ACTH) and 2-5 fold higher (45.7 compared to 8.4 - 20.0 μ g/dl for corticosteroids) than the cage control animals. Three time-averaged brain SAR levels of 0.16, 1.6 and 5 W/kg were tested in a single 2-h RF-field exposure to the Iridium cell phone field. When RF-exposed and sham-exposed (immobilized) animals were compared, no differences were seen in core body temperature, corticosterone or ACTH that could be attributed to near-field RF radiation. Levels of Odc, Fos and Jun mRNA were also monitored in brains of animals exposed to the RF field for 2 h, and they showed no differences from sham-exposed (loose-tube immobilized) animals that were due to RF-field exposure. These data suggest that a significant stress response, indicated by a transient increase in core body temperature, ACTH and corticosterone, occurred in animals placed in even the mild loose-tube immobilization required for near-field RF exposure employed here and in our other studies. Failure to adequately characterize and control this immobilization response with appropriate cage control animals, as described previously, could significantly mask any potential effects mediated by the RF field on these and other stress-related parameters. We conclude that the pulse-modulated digital Iridium RF field at SARs up to 5 W/kg is incapable of altering these stress-related responses. This conclusion is further supported by our use of an RF-field exposure apparatus that minimized immobilization stress; the use of conditioned/tube-trained animals and the measurement of hormonal and molecular markers after 2 h RF-field exposure when the stress-mediated effects were complete further support our conclusion.

Stang A, Anastassiou G, Ahrens W, Broman K, Bornfeld N, Jockel KH, The possible role of radiofrequency radiation in the development of uveal melanoma. *Epidemiology* 12(1):7-12, 2001.

There are few epidemiologic studies dealing with electromagnetic radiation and uveal melanoma. The majority of these studies are exploratory and are based on job and industry titles only. We conducted a hospital-based and population-based case-control study of uveal melanoma and occupational exposures to different sources of electromagnetic radiation, including radiofrequency radiation. We then pooled these results. We interviewed a total of 118 female and male cases with uveal melanoma and 475 controls matching on sex, age, and study regions. Exposure to radiofrequency-transmitting devices was rated as (a) no radiofrequency radiation exposure, (b) possible exposure to mobile phones, or (c) probable/certain exposure to mobile phones. Exposures were rated independently by two of the authors who did not know case or control status. We used conditional logistic regression to calculate odds ratios (ORs) and 95% confidence intervals (95% CIs). We found an elevated risk for exposure to radiofrequency-transmitting devices (exposure to radio sets, OR = 3.0, 95% CI = 1.4-6.3; probable/certain exposure to mobile phones, OR = 4.2, 95% CI = 1.2-14.5). Other sources of electromagnetic radiation such as high-voltage lines, electrical machines, complex electrical environments, visual display terminals, or radar units were not associated with uveal melanoma. This is the first study describing an association between radiofrequency radiation exposure and uveal melanoma. Several methodologic limitations prevent our results from providing clear evidence on the hypothesized association.

Stang A, Schmidt-Pokrzywniak A, Lash TL, Lommatzsch PK, Taubert G, Bornfeld N, Jöckel KH. Mobile Phone Use and Risk of Uveal Melanoma: Results of the Risk Factors for Uveal Melanoma Case-Control Study. *J Natl Cancer Inst.* 2009 Jan 13. [Epub ahead of print]

We recently reported an increased risk of uveal melanoma among mobile phone users. Here, we present the results of a case-control study that assessed the association between mobile phone use and risk of uveal melanoma. We recruited 459 uveal melanoma case patients at the University of Duisburg-Essen and matched 455 case patients with 827 population control subjects, 133 with 180 ophthalmologist control subjects, and 187 with 187 sibling control subjects. We used a questionnaire to assess mobile phone use and estimated odds ratios (ORs) and 95% confidence intervals (95% CIs) of risk for uveal melanoma using conditional logistic regression. Risk of uveal melanoma was not associated with regular mobile

phone use (OR = 0.7, 95% CI = 0.5 to 1.0 vs population control subjects; OR = 1.1, 95% CI = 0.6 to 2.3 vs ophthalmologist control subjects; and OR = 1.2, 95% CI = 0.5 to 2.6 vs sibling control subjects), and we observed no trend for cumulative measures of exposure. We did not corroborate our previous results that showed an increased risk of uveal melanoma among regular mobile phone users.

Stankiewicz W, Dąbrowski MP, Kubacki R, Sobiczewska E, Szmigielski S Immunotropic Influence of 900 MHz Microwave GSM Signal on Human Blood Immune Cells Activated in Vitro. *Electromagnetic Biology and Medicine* 25(1) 45-51, 2006.

In an earlier study we reported that G₀ phase peripheral blood mononuclear cells (PBMC) exposed to low-level (SAR = 0.18 W/kg) pulse-modulated 1300 MHz microwaves and subsequently cultured, demonstrate changed immune activity (Dabrowski et al., 2003). We investigated whether cultured immune cells induced into the active phases of cell cycle (G₁, S) and then exposed to microwaves will also be sensitive to electromagnetic field. An anechoic chamber of our design containing a microplate with cultured cells and an antenna emitting microwaves (900 MHz simulated GSM signal, 27 V/m, SAR 0.024 W/kg) was placed inside the ASSAB incubator. The microcultures of PBMC exposed to microwaves demonstrated significantly higher response to mitogens and higher immunogenic activity of monocytes (LM index) than control cultures. LM index, described in detail elsewhere (Dabrowski et al., 2001), represents the monokine influence on lymphocyte mitogenic response. The results suggest that immune activity of responding lymphocytes and monocytes can be additionally intensified by 900 MHz microwaves.

Stefanics G, Kellenyi L, Molnar F, Kubinyi G, Thurocz G, Hernadi I. Short GSM mobile phone exposure does not alter human auditory brainstem response. *BMC Public Health*. 2007 Nov 12;7(1):325 [Epub ahead of print]

ABSTRACT: BACKGROUND: There are about 1.6 billion GSM cellular phones in use throughout the world today. Numerous papers have reported various biological effects in humans exposed to electromagnetic fields emitted by mobile phones. The aim of the present study was to advance our understanding of potential adverse effects of the GSM mobile phones on the human hearing system. **METHODS:** Auditory Brainstem Response (ABR) was recorded with three non-polarizing Ag-AgCl scalp electrodes in thirty young and healthy volunteers (age 18-26 years) with normal hearing. ABR data were collected before, and immediately after a 10 minute exposure to 900 MHz pulsed electromagnetic field (EMF) emitted by a commercial Nokia 6310 mobile phone. Fifteen subjects were exposed to genuine EMF and fifteen to sham EMF in a double blind and counterbalanced order. Possible effects of irradiation was analyzed by comparing the latency of ABR waves I, III and V before and after genuine/sham EMF exposure. **RESULTS:** Paired sample t-test was conducted for statistical analysis. Results revealed no significant differences in the latency of ABR waves I, III and V before and after 10 minutes of genuine/sham EMF exposure. **CONCLUSIONS:** The present results suggest that, in our experimental conditions, a single 10 minute exposure of 900 MHz EMF emitted by a commercial mobile phone does not produce measurable immediate effects in the latency of auditory brainstem waves I, III and V.

Stefanics G, Thuróczy G, Kellényi L, Hernádi I. Effects of twenty-minute 3G mobile phone irradiation on event related potential components and early gamma synchronization in auditory oddball paradigm. *Neuroscience*. 157(2):453-462, 2008.

We investigated the potential effects of 20 min irradiation from a new generation Universal Mobile Telecommunication System (UMTS) 3G mobile phone on human event related potentials (ERPs) in an auditory oddball paradigm. In a double-blind task design, subjects were exposed to either genuine or sham irradiation in two separate sessions. Before and after irradiation subjects were presented with a random series of 50 ms tone burst (frequent standards: 1 kHz, P=0.8, rare deviants: 1.5 kHz, P=0.2) at a mean repetition rate of 1500 ms while electroencephalogram (EEG) was recorded. The subjects' task was to silently count the appearance of targets. The amplitude and latency of the N100, N200, P200 and P300 components for targets and standards were analyzed in 29 subjects. We found no significant effects of electromagnetic field (EMF) irradiation on the amplitude and latency of the above ERP components. In order to study possible effects of EMF on attentional processes, we applied a wavelet-based time-frequency method to analyze the early gamma component of brain responses to auditory stimuli. We found that the early evoked gamma activity was insensitive to UMTS RF exposition. Our results support the notion, that a single 20 min irradiation from new generation 3G mobile phones does not induce measurable changes in latency or amplitude of ERP components or in oscillatory gamma-band activity in an auditory oddball paradigm.

Stopczyk D, Gnitecki W, Buczynski A, Markuszewski L, Buczynski J. [Effect of electromagnetic field produced by mobile phones on the activity of superoxide dismutase (SOD-1) and the level of malonyldialdehyde (MDA)--in vitro study] *Med Pr.* 53(4):311-314, 2002.

[Article in Polish]

The aim of the study was to assess in vitro the effect of electromagnetic field produced by mobile phones on the activity of superoxide dismutase (SOD-1) and the level of malonyldialdehyde (MDA) in human blood platelets. The suspension of blood platelets was exposed to the electromagnetic field with the frequency of 900 MHz for 1, 3, 5, and 7 min. Our studies demonstrated that microwaves produced by mobile phones significantly depleted SOD-1 activity after 1, 5, and 7 min of exposure and increased after 3 min in comparison with the control test. There was a significant increase in the concentration of MDA after 1, 5, and 7 min and decrease after 3 min of exposure as compared with the control test. On the grounds of our results we conclude that oxidative stress after exposure to microwaves may be the reason for many adverse changes in cells and may cause a number of systemic disturbances in the human body.

Stovner LJ, Oftedal G, Straume A, Johnsson A. Nocebo as headache trigger: evidence from a sham-controlled provocation study with RF fields. *Acta Neurol Scand Suppl.* 188:67-71, 2008.

BACKGROUND: A large proportion of the population in Norway has experienced headache in connection with mobile phone use, but several double-blind provocation studies with radiofrequency (RF) and sham exposures have shown no relation between headache and mobile phone RF fields. **AIMS:** To investigate the type and location of headache experienced by participants in one provocation study in order to gain insight into possible causes and mechanisms of the headaches. **METHOD:** Questionnaire about headache, indication on figure of location of headache after exposure, interview with neurologist about headache features to make headache diagnoses. **RESULTS:** The 17 participants went through 130 trials (sham or RF exposure). No significant difference existed in headache type, laterality or location between the headaches experienced with the two exposures types. In most participants, the headache was compatible with tension-type headache. **DISCUSSION:** As participants experienced their typical 'mobile phone headache' both with and without RF exposure, and since the experiment did not involve the stress or the arm/head position of mobile phone use, the most likely explanation is that the headache in this situation is caused by negative expectations (nocebo). **CONCLUSION:** This and other similar studies indicate that headache occurring in connection with mobile phone use is not related to RF fields, and that a placebo effect is important for this and possibly other headache triggers.

Stronati L, Testa A, Moquet J, Edwards A, Cordelli E, Villani P, Marino C, Freseigna AM, Appolloni M, Lloyd D. 935 MHz cellular phone radiation. An in vitro study of genotoxicity in human lymphocytes. *Int J Radiat Biol.* 82(5):339-346, 2006.

Purpose: The possibility of genotoxicity of radiofrequency radiation (RFR) applied alone or in combination with x-rays was investigated in vitro using several assays on human lymphocytes. The chosen specific absorption rate (SAR) values are near the upper limit of actual energy absorption in localized tissue when persons use some cellular telephones. The purpose of the combined exposures was to examine whether RFR might act epigenetically by reducing the fidelity of repair of DNA damage caused by a well-characterized and established mutagen. **Methods:** Blood specimens from 14 donors were exposed continuously for 24 h to a Global System for Mobile Communications (GSM) basic 935 MHz signal. The signal was applied at two SAR; 1 and 2 W/Kg, alone or combined with a 1-min exposure to 1.0 Gy of 250 kVp x-rays given immediately before or after the RFR. The assays employed were the alkaline comet technique to detect DNA strand breakage, metaphase analyses to detect unstable chromosomal aberrations and sister chromatid exchanges, micronuclei in cytokinesis-blocked binucleate lymphocytes and the nuclear division index to detect alterations in the speed of in vitro cell cycling. **Results:** By comparison with appropriate sham-exposed and control samples, no effect of RFR alone could be found for any of the assay endpoints. In addition RFR did not modify any measured effects of the x-radiation. **Conclusions:** This study has used several standard in vitro tests for chromosomal and DNA damage in human lymphocytes exposed in vitro to a combination of x-rays and RFR. It has comprehensively examined whether a 24-h continuous exposure to a 935 MHz GSM basic signal delivering SAR of 1 or 2 W/Kg is genotoxic per se or whether, it

can influence the genotoxicity of the well-established clastogenic agent; x-radiation. Within the experimental parameters of the study in all instances no effect from the RFR signal was observed.

Sukhotina I, Streckert JR, Bitz AK, Hansen VW, Lerchl A. 1800 MHz electromagnetic field effects on melatonin release from isolated pineal glands. J Pineal Res. 40(1):86-91, 2006.

Isolated pineal glands of Djungarian hamsters (*Phodopus sungorus*) were continuously perfused by Krebs-Ringer buffer, stimulated with the beta-adrenergic receptor agonist isoproterenol to induce melatonin synthesis, and exposed for 7 hr to a 1800 MHz continuous wave (CW) or pulsed GSM (Global System for Mobile Communications)-modulated electromagnetic signal at specific absorption rate (SAR) rates of 8, 80, 800, and 2700 mW/kg. Experiments were performed in a blind fashion. Perifusate samples were collected every hour, and melatonin concentrations were measured by a specific radioimmunoassay. Both types of signal significantly enhanced melatonin release at 800 mW/kg SAR, while at 2700 mW/kg SAR, melatonin levels were elevated in the CW, but suppressed in the GSM-exposed pineal glands. As a temperature rise of approximately 1.2 degrees C was measured at 2700 mW/kg SAR, effects at this level are thermal. With regard to radiofrequency electromagnetic fields, the data do not support the 'melatonin hypothesis,' according to which nonthermal exposure suppresses melatonin synthesis.

Sun LX, Yao K, He JL, Lu DQ, Wang KJ, Li HW. [Effect of acute exposure to microwave from mobile phone on DNA damage and repair of cultured human lens epithelial cells in vitro.] Zhonghua Lao Dong Wei Sheng Zhi Ye Bing Za Zhi. 24(8):465-467, 2006.

[Article in Chinese]

OBJECTIVE: To investigate the DNA damage of human lens epithelial cells (LECs) caused by acute exposure to low-power 217 Hz modulated 1.8 GHz microwave radiation and DNA repair. METHODS: Cultured LECs were exposed to 217 Hz modulated 1.8 GHz microwave radiation at SAR (specific absorption rate) of 0, 1, 2, 3 and 4 W/kg for 2 hours in an sXc-1800 incubator and irradiate system. The DNA single strand breaks were detected with comet assay in sham-irradiated cells and irradiated cells incubated for varying periods: 0, 30, 60, 120 and 240 min after irradiation. Images of comets were digitized and analyzed using an Imagine-pro plus software, and the indexes used in this study were tail length (TL) and tail moment (TM). RESULTS: The difference in DNA-breaks between the exposure and sham exposure groups induced by 1 and 2 W/kg irradiation was not significant at every detect time ($P > 0.05$). As for the dosage of 3 and 4 W/kg there was difference in both group immediately after irradiation ($P < 0.01$). At the time of 30 min after irradiation the difference went on at both group ($P < 0.01$). However, the difference disappeared after one hour's incubation in 3 W/kg group ($P > 0.05$), and existed in 4 W/kg group. CONCLUSION: No or repairable DNA damage was observed after 2 hour irradiation of 1.8 GHz microwave on LECs when $SAR \leq 3$ W/kg. The DNA damages caused by 4 W/kg irradiation were irreversible.

Sun LX, Yao K, Jiang H, He JL, Lu DQ, Wang KJ, Li HW [DNA damage and repair induced by acute exposure of microwave from mobile phone on cultured human lens epithelial cells] Zhonghua Yan Ke Za Zhi. 42(12):1084-1088, 2006..

[Article in Chinese]

.OBJECTIVE: To investigate the effects of acute exposure of low-power 217 Hz modulated 1.8 GHz microwave radiation on the DNA damage of human lens epithelial cells (hLECs) and repair. METHODS: Cultured hLECs were exposed to 217 Hz modulated 1.8 GHz microwave radiation at SAR (specific absorption rate) of 1.0, 2.0, 3.0 and 4.0 W/kg for 2 hours in an sXc-1800 incubator and irradiate system, the DNA single strand breaks were detected with comet assay (single-cell gel electrophoresis) in sham-irradiated cells and irradiated cells incubated for varying periods: 0, 30 and 60 minutes after irradiation. Images of comets were digitized and analyzed using an Imagine-pro plus software, and the indexes used in this study were tail length (TL) and tail moment (TM). BrdU was added into the medium with additional one hour incubation after radiation, the cell proliferation rate was determined using a BrdU-kit. RESULTS: The difference of DNA-breaks between the exposure and sham exposure groups induced by 1.0 and 2.0 W/kg irradiation were not

significant in each time points ($P > 0.05$) ; there were significant difference in both groups at the exposure dose of 3.0 and 4.0 W/kg immediately and at the time of 30 minutes after irradiation ($P < 0.01$) ; if the radiation exposure time was beyond one hour no differences were able to be detected in 3.0 W/kg group ($P > 0.05$) compared with control, but the evidence of significant DNA damage still existed in 4.0 W/kg group at the same time point. Cell proliferation rate had no significant difference when the application of SAR was ≤ 3.0 W/kg ($P > 0.05$) , however the cell proliferation was decreased significantly at the dose of 4.0 W/kg irradiation ($P < 0.01$). **CONCLUSIONS:** No effective DNA damage was induced using comet assay after 2 hours irradiation of 1.8 GHz microwave on hLECs at the dose SAR ≤ 3.0 W/kg. 4.0 W/kg irradiation caused significantly DNA damage and inhibition of hLECs proliferation.

Sykes PJ, McCallum BD, Bangay MJ, Hooker AM, Morley AA. Effect of Exposure to 900 MHz Radiofrequency Radiation on Intrachromosomal Recombination in pKZ1 Mice. *Radiat Res* 156(5):495-502, 2001.

Radiofrequency (RF) radiation emitted from mobile phones is not considered to be directly genotoxic, but it may have downstream effects on cellular DNA. We studied the effect of 4 W/kg pulsed 900 MHz RF radiation on somatic intrachromosomal recombination in the spleen in the pKZ1 recombination mutagenesis model. Somatic intrachromosomal recombination inversion events were detected in spleen tissue of pKZ1 mice by histochemical staining for E. coli beta-galactosidase protein in cells in which the lacZ transgene has undergone an inversion event. pKZ1 mice were exposed daily for 30 min to plane-wave fields of 900 MHz with a pulse repetition frequency of 217 Hz and a pulse width of 0.6 ms for 1, 5 or 25 days. Three days after the last exposure, spleen sections were screened for DNA inversion events. There was no significant difference between the control and treated groups in the 1- and 5-day exposure groups, but there was a significant reduction in inversions below the spontaneous frequency in the 25-day exposure group. This observation suggests that exposure to RF radiation can lead to a perturbation in recombination frequency which may have implications for recombination repair of DNA. The biological significance of a reduction below the spontaneous frequency is not known. The number of mice in each treatment group in this study was small ($n = 10$ or $n = 20$). Therefore, repetition of this study with a larger number of animals is required to confirm these observations.

Tafforeau M, Verdu M-C, Norris V, White G, Demarty M, Thellier M, Ripoll C. SIMS study of the calcium-deprivation step related to epidermal meristem production induced in flax by cold shock or radiation from a GSM telephone. *J Trace Microprobe Tech* 20(4):611-623, 2002.

Exposing seedlings of the flax, *Linum usitatissimum* L., to a variety of weak environmental stresses plus a 2-day calcium deprivation triggers the common response of production of epidermal meristems in the hypocotyls. Here, we show that the same response was induced by a 1 min cold shock. Epidermal meristem production was also induced by a single 2-h exposure to radiation emitted at 0.9 GHz at non-thermal levels by a GSM telephone. This flax-based system is therefore well suited to studying the effects of low intensity stimuli, including those of electromagnetic radiation. To begin to determine the underlying mechanisms, in which calcium is implicated, it is desirable to analyse the changes in ions in the tissues affected. We therefore performed a Secondary Ion Mass Spectrometry (SIMS) study of the distribution of the main inorganic cations in the hypocotyl of control and calcium-deprived seedlings. This showed decreases in calcium, sodium and potassium and an increase in magnesium that did not alter substantially the overall ratio of divalent to monovalent cations.

Tahvanainen K, Niño J, Halonen P, Kuusela T, Laitinen T, Länsimies E, Hartikainen J, Hietanen M, Lindholm H. Cellular phone use does not acutely affect blood pressure or heart rate of humans. *Bioelectromagnetics* 25:73-83, 2004.

A recent study raised concern about increase of resting blood pressure after a 35 min exposure to the radiofrequency (RF) field emitted by a 900 MHz cellular phone. In this randomized, double blind, placebo controlled crossover trial, 32 healthy subjects were submitted to 900 MHz (2 W), 1800 MHz (1 W) cellular phone exposure, and to sham exposure in separate sessions. Arterial blood pressure (arm cuff method) and heart rate were measured during and after the 35 min RF and sham exposure sessions. We evaluated cardiovascular responses in terms of blood pressure and heart rate during controlled breathing, spontaneous breathing, head-up tilt table test, Valsalva manoeuvre and deep breathing test. Arterial blood pressure and heart rate

did not change significantly during or after the 35 min RF exposures at 900 MHz or 1800 MHz, compared to sham exposure. The results of this study indicate that exposure to a cellular phone, using 900 MHz or 1800 MHz with maximal allowed antenna powers, does not acutely change arterial blood pressure and heart rate

Tahvanainen K, Nino J, Halonen P, Kuusela T, Alanko T, Laitinen T, Lansimies E, Hietanen M, Lindholm H. Effects of cellular phone use on ear canal temperature measured by NTC thermistors. Clin Physiol Funct Imaging. 27(3):162-172, 2007.

The earlier studies using phantom models and human subjects concerning warming effects during cellular phone use have been controversial, partly because radiofrequency (RF) exposures have been variable. In this randomized, double-blind, placebo-controlled crossover trial, 30 healthy subjects were submitted to 900 MHz (2W) and 1800 MHz (1W) cellular phone RF exposure, and to sham exposure in separate study sessions. Temperature signals were recorded continuously in both ear canals before, during and after the 35-min RF exposure and the 35-min sham exposure sessions. Temperature was measured by using small-sized NTC thermistors placed in the ear canals through disposable ear plugs. The mean temperature changes were determined during a set cardiovascular autonomic function studies: during a 5-min controlled breathing test, during a 5-min spontaneous breathing test, during 7-min head-up tilting, 1-min before, during and after two consecutive Valsalva manoeuvres and during a deep breathing test. Temperatures in the exposed ear were significantly higher during RF exposures compared with sham exposure in both 900 and 1800 MHz studies with maximum differences of 1.2 +/- 0.5 degrees C (900 MHz exposure) and 1.3 +/- 0.7 degrees C (1800 MHz exposure). Temperatures in the RF-exposed ear were also significantly higher during the postexposure period compared with post-sham exposure period with maximum differences of 0.6 +/- 0.3 degrees C for 900 MHz and 0.5 +/- 0.5 degrees C for 1800 MHz. The results of this study suggest that RF exposure to a cellular phone, either using 900 or 1800 MHz with their maximal allowed antenna powers, increases the temperature in the ear canal. The reason for the ear canal temperature rising is a consequence of mobile phone battery warming during maximal antenna power use. The earlier published articles do not indicate that temperature rising in the ear canal has any significant contribution from the RF fields emitted from mobile phones.

Takahashi S, Inaguma S, Cho Y-M, Imaida K, Wang J, Fujiwara O, Shirai T, Lack of Mutation Induction with Exposure to 1.5 GHz Electromagnetic Near Fields Used for Cellular Phones in Brains of Big Blue Mice. Cancer Res 62:1956-1960, 2002.

The possible mutagenic potential of exposure to 1.5 GHz electromagnetic near field (EMF) was investigated using brain tissues of Big Blue mice (BBM). Male BBM were locally exposed to EMF in the head region at 2.0, 0.67, and 0 W/kg specific absorption rate for 90 min/day, 5 days/week, for 4 weeks. No gliosis or degenerative lesions were histopathologically noted in brain tissues, and no obvious differences in Ki-67 labeling and apoptotic indices of glial cells were evident among the groups. There was no significant variation in the frequency of independent mutations of the *lacI* transgene in the brains. G:C to A:T transitions at CpG sites constituted the most prevalent mutations in all groups and at all time points. Deletion mutations were slightly increased in both the high and low EMF exposure groups as compared with the sham-exposed group, but the differences were not statistically significant. These findings suggest that exposure to 1.5 GHz EMF is not mutagenic to mouse brain cells and does not create any increased hazard with regard to brain tumor development.

Takebayashi T, Akiba S, Kikuchi Y, Taki M, Wake K, Watanabe S, Yamaguchi N. Mobile phone use and acoustic neuroma risk in Japan. Occup Environ Med. 2006 Aug 15; [Epub ahead of print]

OBJECTIVES: The rapid increase of mobile phone use has increased public concern about its possible health effects in Japan, where the mobile phone system is unique in terms of the characteristics of the signal transmission. To examine the relationship between mobile phone use and acoustic neuroma, a case-control study was initiated. **METHODS:** The study followed the common, core protocol of the international collaborative study, INTERPHONE study. A prospective case recruitment was done in Japan for 2000-2004. One hundred and one acoustic neuroma cases, who were 30-69 years of age and resided in the Tokyo area, and 339 age-, sex-, and residency-matched controls were interviewed using a common computer-assisted personal interview system. Education- and marital status-adjusted odds ratio was calculated with a conditional logistic regression analysis. **RESULTS:** Fifty-one cases (52.6%) and 192 controls (58.2%) were regular mobile phone users on the reference date, which was set as 1 year before the diagnosis, and no significant increase of

acoustic neuroma risk was observed, with the odds ratio (OR) being 0.73 (95% confidence interval : 0.43-1.23). No exposure-related increase in the risk of acoustic neuroma was observed when the cumulative length of use (<4 years, 4-8 years, >8years) or cumulative call time (<300 h, 300-900 h, >900h) was used as an exposure index. The OR was 1.09 (95% CI:0.58-2.06) when the reference date was set as 5 years before the diagnosis. Further, laterality of mobile phone use was not associated with tumors. CONCLUSIONS: These results suggest that there is no significant increase in the risk of acoustic neuroma in association with mobile phone use in Japan.

Takebayashi T, Varsier N, Kikuchi Y, Wake K, Taki M, Watanabe S, Akiba S, Yamaguchi N. Mobile phone use, exposure to radiofrequency electromagnetic field, and brain tumour: a case-control study. *Br J Cancer*. 98(3):652-659, 2008.

In a case-control study in Japan of brain tumours in relation to mobile phone use, we used a novel approach for estimating the specific absorption rate (SAR) inside the tumour, taking account of spatial relationships between tumour localisation and intracranial radiofrequency distribution. Personal interviews were carried out with 88 patients with glioma, 132 with meningioma, and 102 with pituitary adenoma (322 cases in total), and with 683 individually matched controls. All maximal SAR values were below 0.1 W kg⁻¹, far lower than the level at which thermal effects may occur, the adjusted odds ratios (ORs) for regular mobile phone users being 1.22 (95% confidence interval (CI): 0.63-2.37) for glioma and 0.70 (0.42-1.16) for meningioma. When the maximal SAR value inside the tumour tissue was accounted for in the exposure indices, the overall OR was again not increased and there was no significant trend towards an increasing OR in relation to SAR-derived exposure indices. A non-significant increase in OR among glioma patients in the heavily exposed group may reflect recall bias.

Terao Y, Okano T, Furubayashi T, Ugawa Y. Effects of thirty-minute mobile phone use on visuo-motor reaction time. *Clin Neurophysiol*. 2006 Sep 25; [Epub ahead of print]

OBJECTIVE: To investigate whether exposure to pulsed high-frequency electromagnetic field (pulsed EMF) emitted by a mobile phone has short-term effects on the visuo-motor choice reaction time (RT) and movement time (MT). METHODS: A double blind, counterbalanced crossover design was employed. In 16 normal subjects, we studied the performance of a visuo-motor precued choice reaction time task (PCRT) before and after exposure to EMF emitted by a mobile phone for 30 minutes or sham exposure. RESULTS: The RTs and MTs under different conditions of precue information were not affected by exposure to pulsed EMF emitted by a mobile phone or by sham phone use. CONCLUSIONS: Thirty minutes of mobile phone use has no significant short-term effect on the cortical visuo-motor processing as studied by the present PCRT task. SIGNIFICANCE: This is the first study to investigate visuo-motor behavior in relation to mobile phone exposure. No significant effect of mobile phone use was demonstrated on the performance of the visuo-motor reaction time task.

Terao Y, Okano T, Furubayashi T, Yugeta A, Inomata-Terada S, Ugawa Y Effects of thirty-minute mobile phone exposure on saccades. *Clin Neurophysiol*. 118(7):1545-1556, 2007.

OBJECTIVE: To investigate whether exposure to pulsed high-frequency electromagnetic field (pulsed EMF) emitted by a mobile phone has short-term effects on saccade performances. METHODS: A double blind, counterbalanced crossover design was employed. In 10 normal subjects, we studied the performance of visually guided saccade (VGS), gap saccade (GAP), and memory guided saccade (MGS) tasks before and after exposure to EMF emitted by a mobile phone for thirty minutes or sham exposure. We also implemented a hand reaction time (RT) task in response to a visual signal. RESULTS: With the exception of VGS and MGS latencies, the parameters of VGS, GAP and MGS tasks were unchanged before and after real or sham EMF exposure. In addition, the latencies of VGS and MGS did not change differently after real and sham exposure. The hand RT shortened with the repetition of trials, but again this trend was of similar magnitude for real and sham exposures. CONCLUSIONS: Thirty minutes of mobile phone exposure has no significant short-term effect on saccade performances. SIGNIFICANCE: This is the first study to investigate saccade performance in relation to mobile phone exposure. No significant effect of mobile phone use was demonstrated on the performance of various saccade tasks, suggesting that the cortical processing for saccades and attention is not affected by exposure to EMF emitted by a mobile phone.

Testylier G, Tonduli L, Malabiau R, Debouzy JC. Effects of exposure to low level radiofrequency fields on acetylcholine release in hippocampus of freely moving rats. *Bioelectromagnetics* 23:249-255, 2002.

Some central cholinergic effects have been reported in animals after acute exposure to radiofrequency electromagnetic field at low intensity. We studied acetylcholine (ACh) release in the brain of freely moving rats exposed for 1 h during the day to a 2.45 GHz continuous wave radiofrequency field (RF) (2 or 4 mW/cm²) or exposed for 1 or 14 h during the night to a 800 MHz field modulated at 32 Hz (AM 200 mW/cm²). Measurements were performed by microdialysis using a membrane implanted through the upper CA1 region of the hippocampus. After irradiation with the 2.45 GHz RF, rats exposed at 2 mW/cm² did not show a significant modification of ACh release, whereas those exposed at 4 mW/cm² showed a significant 40% decrease in mean ACh release from hippocampus. This decrease was maximal at 5 h post exposure. Exposure to the 800 MHz RF for 1 h did not cause any significant effect, but exposure for 14 hrs induced a significant 43% decrease in ACh release during the period 11 p.m.-4 a.m. compared to control rats. In the control group we observed an increase of ACh release at the beginning of the night, which was linked to the waking period of rats. This normal increase was disturbed in rats exposed overnight to the 800 MHz RF. This work indicates that neurochemical modification of the hippocampal cholinergic system can be observed during and after an exposure to low intensity RF.

Thorlin, T., Rouquette, J.-M., Hamnerius, Y., Hansson, E., Persson, M., Bjorklund, U., Rosengren, L., Ronnback, L. and Persson, M. Exposure of Cultured Astroglial and Microglial Brain Cells to 900 MHz Microwave Radiation. *Radiat. Res.* 166, 409-421, 2006.

The rapid rise in the use of mobile communications has raised concerns about health issues related to low-level microwave radiation. The head and brain are usually the most exposed targets in mobile phone users. In the brain, two types of glial cells, the astroglial and the microglial cells, are interesting in the context of biological effects from microwave exposure. These cells are widely distributed in the brain and are directly involved in the response to brain damage as well as in the development of brain cancer. The aim of the present study was to investigate whether 900 MHz radiation could affect these two different glial cell types in culture by studying markers for damage-related processes in the cells. Primary cultures enriched in astroglial cells were exposed to 900 MHz microwave radiation in a temperature-controlled exposure system at specific absorption rates (SARs) of 3 W/kg GSM modulated wave (mw) for 4, 8 and 24 h or 27 W/kg continuous wave (cw) for 24 h, and the release into the extracellular medium of the two pro-inflammatory cytokines interleukin 6 (Il6) and tumor necrosis factor-alpha (Tnfa) was analyzed. In addition, levels of the astroglial cell-specific reactive marker glial fibrillary acidic protein (Gfap), whose expression dynamics is different from that of cytokines, were measured in astroglial cultures and in astroglial cell-conditioned cell culture medium at SARs of 27 and 54 W/kg (cw) for 4 or 24 h. No significant differences could be detected for any of the parameters studied at any time and for any of the radiation characteristics. Total protein levels remained constant during the experiments. Microglial cell cultures were exposed to 900 MHz radiation at an SAR of 3 W/kg (mw) for 8 h, and Il6, Tnfa, total protein and the microglial reactivity marker ED-1 (a macrophage activation antigen) were measured. No significant differences were found. The morphology of the cultured astroglial cells and microglia was studied and appeared to be unaffected by microwave irradiation. Thus this study does not provide evidence for any effect of the microwave radiation used on damage-related factors in glial cells in culture.

Tice RR, Hook GG, Donner M, McRee DI, Guy AW. Genotoxicity of radiofrequency signals. I. Investigation of DNA damage and micronuclei induction in cultured human blood cells. *Bioelectromagnetics* 23:113-126, 2002.

As part of a comprehensive investigation of the potential genotoxicity of radiofrequency (RF) signals emitted by cellular telephones, in vitro studies evaluated the induction of DNA and chromosomal damage in human blood leukocytes and lymphocytes, respectively. The signals were voice modulated 837 MHz produced by an analog signal generator or by a time division multiple access (TDMA) cellular telephone, 837 MHz generated by a code division multiple access (CDMA) cellular telephone (not voice modulated), and voice modulated 1909.8 MHz generated by a global system of mobile communication (GSM)-type personal communication systems (PCS) cellular telephone. DNA damage (strand breaks/alkali labile sites) was assessed in leukocytes using the alkaline (pH>13) single cell gel electrophoresis (SCG) assay. Chromosomal damage was evaluated in lymphocytes mitogenically stimulated to divide postexposure using the cytochalasin B-binucleate cell micronucleus assay. Cells were exposed at 37±1°C, for 3 or 24 h at average specific absorption rates (SARs) of 1.0-10.0 W/kg. Exposure for either 3 or 24 h did not induce a significant increase in DNA damage in leukocytes, nor did exposure for 3 h induce a significant

increase in micronucleated cells among lymphocytes. However, exposure to each of the four RF signal technologies for 24 h at an average SAR of 5.0 or 10.0 W/kg resulted in a significant and reproducible increase in the frequency of micronucleated lymphocytes. The magnitude of the response (approximately four fold) was independent of the technology, the presence or absence of voice modulation, and the frequency (837 vs. 1909.8 MHz). This research demonstrates that, under extended exposure conditions, RF signals at an average SAR of at least 5.0 W/kg are capable of inducing chromosomal damage in human lymphocytes.

Tillmann T, Ernst H, Ebert S, Kuster N, Behnke W, Rittinghausen S, Dasenbrock C. Carcinogenicity study of GSM and DCS wireless communication signals in B6C3F1 mice. *Bioelectromagnetics*. 2006 Oct 3; [Epub ahead of print]

The purpose of this study using a total of 1170 B6C3F1 mice was to detect and evaluate possible carcinogenic effects in mice exposed to radio-frequency-radiation (RFR) from Global System for Mobile Communication (GSM) and Digital Personal Communications System (DCS) handsets as emitted by handsets operating in the center of the communication band, that is, at 902 MHz (GSM) and 1747 MHz (DCS). Restrained mice were exposed for 2 h per day, 5 days per week over a period of 2 years to three different whole-body averaged specific absorption rate (SAR) levels of 0.4, 1.3, 4.0 mW/g bw (SAR), or were sham exposed. Regarding the organ-related tumor incidence, pairwise Fisher's test did not show any significant increase in the incidence of any particular tumor type in the RF exposed groups as compared to the sham exposed group. Interestingly, while the incidences of hepatocellular carcinomas were similar in EMF and sham exposed groups, in both studies the incidences of liver adenomas in males decreased with increasing dose levels; the incidences in the high dose groups were statistically significantly different from those in the sham exposed groups. Comparison to published tumor rates in untreated mice revealed that the observed tumor rates were within the range of historical control data. In conclusion, the present study produced no evidence that the exposure of male and female B6C3F1 mice to wireless GSM and DCS radio frequency signals at a whole body absorption rate of up to 4.0 W/kg resulted in any adverse health effect or had any cumulative influence on the incidence or severity of neoplastic and non-neoplastic background lesions, and thus the study did not provide any evidence of RF possessing a carcinogenic potential.

Tiwari R, Lakshmi NK, Surender V, Rajesh AD, Bhargava SC, Ahuja YR. Combinative exposure effect of radio frequency signals from CDMA mobile phones and aphidicolin on DNA integrity. *Electromagn Biol Med*. 27(4):418-425, 2008.

The aim of present study is to assess DNA integrity on the effect of exposure to a radio frequency (RF) signal from Code Division Multiple Access (CDMA) mobile phones. Whole blood samples from six healthy male individuals were exposed for RF signals from a CDMA mobile phone for 1 h. Alkaline comet assay was performed to assess the DNA damage. The combinative exposure effect of the RF signals and APC at two concentrations on DNA integrity was studied. DNA repair efficiency of the samples was also studied after 2 h of exposure. The RF signals and APC (0.2 microg/ml) alone or in synergism did not have any significant DNA damage as compared to sham exposed. However, univariate analysis showed that DNA damage was significantly different among combinative exposure of RF signals and APC at 0.2 microg/ml ($p < 0.05$) and at 2 microg/ml ($p < 0.02$). APC at 2 microg/ml concentration also showed significant damage levels ($p < 0.05$) when compared to sham exposed. DNA repair efficiency also varied in a significant way in combinative exposure sets ($p < 0.05$). From these results, it appears that the repair inhibitor APC enhances DNA breaks at 2 microg/ml concentration and that the damage is possibly repairable. Thus, it can be inferred that the in vitro exposure to RF signals induces reversible DNA damage in synergism with APC.

Tkalec M, Malaric K, Pevalek-Kozlina B. Influence of 400, 900, and 1900 MHz electromagnetic fields on Lemna minor growth and peroxidase activity. *Bioelectromagnetics*. 26(3):185-193, 2005.

Increased use of radio and microwave frequencies requires investigations of their effects on living organisms. Duckweed (*Lemna minor* L.) has been commonly used as a model plant for environmental monitoring. In the present study, duckweed growth and peroxidase activity was evaluated after exposure in a Gigahertz Transversal Electromagnetic (GTEM) cell to electric fields of frequencies 400, 900, and 1900 MHz. The growth of plants exposed for 2 h to the 23 V/m electric field of 900 MHz significantly decreased in comparison with the control, while an electric field of the same strength but at 400 MHz did not have such effect. A modulated field at 900 MHz strongly inhibited the growth, while at

400 MHz modulation did not influence the growth significantly. At both frequencies a longer exposure mostly decreased the growth and the highest electric field (390 V/m) strongly inhibited the growth. Exposure of plants to lower field strength (10 V/m) for 14 h caused significant decrease at 400 and 1900 MHz while 900 MHz did not influence the growth. Peroxidase activity in exposed plants varied, depending on the exposure characteristics. Observed changes were mostly small, except in plants exposed for 2 h to 41 V/m at 900 MHz where a significant increase (41%) was found. Our results suggest that investigated electromagnetic fields (EMFs) might influence plant growth and, to some extent, peroxidase activity. However, the effects of EMFs strongly depended on the characteristics of the field exposure.

Trosić I, Pavčić I. Disturbance of cell proliferation in response to mobile phone frequency radiation. Arh Hig Rada Toksikol. 60(1):109-115, 2009.

The aim of study was to determine the influence of mobile phone frequency radiation on the proliferation, cytoskeleton structure, and mitotic index of V79 cells after 1 h, 2 h, and 3 h of exposure. V79 cells were cultured in standard laboratory conditions and exposed to continuous-wave (CW) RF/MW radiation of 935 MHz, electric field strength of (8.2 ± 0.3) V m⁻¹, and specific absorption rate (SAR) of 0.12 W kg⁻¹. To identify proliferation kinetics, the cells were counted for each hour of exposure 24 h, 48 h, 72 h, and 96 h after respective exposures. Microtubule proteins were determined using specific immunocytochemical methods. Cell smears were analysed under a fluorescent microscope. The study included negative and positive controls. Mitotic index was determined by estimating the number of dividing cells 24 h after exposure and dividing it with the total number of cells. In comparison to the controls, cell proliferation declined in cells exposed for three hours 72 h after irradiation ($p < 0.05$). Microtubule structure was clearly altered immediately after three hours of irradiation ($p < 0.05$). The mitotic index in RF/MW-exposed cells did not differ from negative controls. However, even if exposure did not affect the number of dividing cells, it may have slowed down cell division kinetics as a consequence of microtubule impairment immediately after exposure.

Tsurita G, Nagawa H, Ueno S, Watanabe S, Taki M, Biological and morphological effects on the brain after exposure of rats to a 1439 MHz TDMA field. *Bioelectromagnetics* 21(5):364-371, 2000.

We investigated the effects of exposure to a 1439 MHz TDMA (Time Division Multiple Access) field, as used in cellular phones, on the permeability of the blood-brain barrier (BBB), on the morphological changes of the brain, and on body-mass fluctuations. Male Sprague-Dawley (SD) rats were divided into Three groups of eight rats each. The rats in the EM(+) group, which had their heads arrayed in a circle near the central antenna of an exposure system, were exposed to a 1439 MHz field for one hour a day. The rats in EM(-) group were also in the exposure system, however, without high-frequency electromagnetic wave (HF-EMW) exposure. The animals in the control group were neither placed in the system nor exposed to HF-EMWs. The exposure period was two or four weeks. The energy dose rate peaked at 2 W/kg in the brain; the average over the whole body was 0.25 W/kg. The changes in the permeability of BBB were investigated by Evans blue injection method and by immunostaining of serum albumin. HF-EMWs had no effect on the permeability of BBB. The morphological changes in the cerebellum were investigated by assessing the degeneration of Purkinje cells and the cell concentration in the granular layer. No significant changes were observed in the groups of rats exposed to HF-EMWs for two or four weeks. Averaged body masses were not affected by HF-EMWs exposure. In conclusion, a 1439 MHz TDMA field did not induce observable changes in the permeability of the BBB, morphological changes in the cerebellums, or body mass changes in rats, as evaluated by the conventional methods.

Tuschl H, Novak W, Molla-Djafari H. In vitro effects of GSM modulated radiofrequency fields on human immune cells. *Bioelectromagnetics*. 2005 Dec 8; [Epub ahead of print]

Despite the important role of the immune system in defending the body against infections and cancer, only few investigations on possible effects of radiofrequency (RF) radiation on function of human immune cells have been undertaken. Aim of the present investigation was therefore to assess whether GSM modulated RF fields have adverse effects on the functional competence of human immune cells. Within the frame of the multidisciplinary project "Biological effects of high frequency electromagnetic fields (EMF)" sponsored by the National Occupation Hazard Insurance Association (AUVA) in vitro investigations were carried out on human blood cells. Exposure was performed at GSM Basic 1950 MHz, an SAR of 1 mW/g in an intermittent mode (5 min "ON", 10 min "OFF") and a maximum Delta T of 0.06 degrees C for the duration of 8 h. The following immune parameters were evaluated: (1) the intracellular production of interleukin-2 (IL-2) and interferon (INF) gamma in lymphocytes, and IL-1 and tumor necrosis factor (TNF)-

alpha in monocytes were evaluated with monoclonal antibodies. (2) The activity of immune-relevant genes (IL 1-alpha and beta, IL-2, IL-2-receptor, IL-4, macrophage colony stimulating factor (MCSF)-receptor, TNF-alpha, TNF-alpha-receptor) and housekeeping genes was analyzed with real time PCR. (3) The cytotoxicity of lymphokine activated killer cells (LAK cells) against a tumor cell line was determined in a flow cytometric test. For each parameter, blood samples of at least 15 donors were evaluated. No statistically significant effects of exposure were found and there is no indication that emissions from mobile phones are associated with adverse effects on the human immune system.

Uloziene I, Uloza V, Gradauskiene E, Saferis V. Assessment of potential effects of the electromagnetic fields of mobile phones on hearing. BMC Public Health. 5(1):39, 2005. [Epub ahead of print]

BACKGROUND: Mobile phones have become indispensable as communication tools; however, to date there is only a limited knowledge about interaction between electromagnetic fields (EMF) emitted by mobile phones and auditory function. The aim of the study was to assess potential changes in hearing function as a consequence of exposure to low-intensity EMF's produced by mobile phones at frequencies of 900 and 1800 MHz. **METHODS:** The within-subject study was performed on thirty volunteers (age 18-30 years) with normal hearing to assess possible acute effect of EMF. Participants attended two sessions: genuine and sham exposure of EMF. Hearing threshold levels (HTL) on pure tone audiometry (PTA) and transient evoked otoacoustic emissions (TEOAE's) were recorded before and immediately after 10 min of genuine and/or sham exposure of mobile phone EMF. The administration of genuine or sham exposure was double blind and counterbalanced in order. **RESULTS:** Statistical analysis revealed no significant differences in the mean shift of PTA and TEOAE's values before and after genuine and/or sham mobile phone EMF 10 min exposure. The data collected showed that average TEOAE levels (averaged across a frequency range) changed less than 2 dB between pre- and post-, real and sham exposure. The greatest individual change was 10dB(A), with a decrease in level from pre- to post- real exposure. **CONCLUSIONS:** It could be concluded that a 10-min close exposure of EMFs emitted from a mobile phone had no immediate after-effect on measurements of HTL of PTA and TEOAEs in young adult human subjects and no measurable hearing deterioration was detected in our study.

Unterlechner M, Sauter C, Schmid G, Zeithofer J. No effect of an UMTS mobile phone-like electromagnetic field of 1.97 GHz on human attention and reaction time. Bioelectromagnetics. 2007 Oct 23; [Epub ahead of print]

Several studies in the past reported influences of electromagnetic emissions of GSM phones on reaction time in humans. However, there are currently only a few studies available dealing with possible effects of the electromagnetic fields emitted by UMTS mobile phones. In our study, 40 healthy volunteers (20 female, 20 male), aged 26.0 years (range 21-30 years) underwent four different computer tests measuring reaction time and attention under three different UMTS mobile phone-like exposure conditions (two exposure levels plus sham exposure). Exposure of the subjects was accomplished by small helical antennas operated close to the head and fed by a generic signal representing the emissions of a UMTS mobile phone under constant receiving conditions as well as under a condition of strongly varying transmit power. In the high exposure condition the resulting peak spatial average exposure of the test subjects in the cortex of the left temporal lobe of the brain was 0.63 W/kg (min. 0.25 W/kg, max. 1.49 W/kg) in terms of 1 g averaged SAR and 0.37 W/kg (min. 0.16 W/kg, max. 0.84 W/kg) in terms of 10 g averaged SAR, respectively. Low exposure condition was one-tenth of high exposure and sham was at least 50 dB below low exposure. Statistical analysis of the obtained test parameters showed that exposure to the generic UMTS signal had no statistically significant immediate effect on attention or reaction. Therefore, this study does not provide any evidence that exposure of UMTS mobiles interferes with attention under short-term exposure conditions.

Urban, P, Lukas, E, Roth, Z, Does acute exposure to the electromagnetic field emitted by a mobile phone influence visual evoked potentials? A pilot study. Cent Eur J Public Health 6(4):288-290, 1998.

To search for a potential negative influence on the central nervous system (CNS) of the electromagnetic field emitted by a mobile phone, the authors performed a pilot experimental study of the influence of a single short acute exposure to the GSM mobile phone Motorola 8700, using visual evoked potentials (VEP) examination as an electrophysiological marker of CNS dysfunction. The study group consisted of 20 healthy volunteers. The duration of exposure was 5 minutes. The output power of the device was

1.5 W when the antenna was pulled up. Five parameters of VEP were evaluated by means of multifactorial ANOVA. Confounding effects of age, sex, and of the call in itself were taken into consideration. No statistically significant influence of the above-described exposure to the electromagnetic field emitted by the mobile phone on latencies or amplitudes of VEP was observed.

Utteridge TD, Gebiski V, Finnie JW, Vernon-Roberts B, Kuchel TR. Long-Term Exposure of E μ im1 Transgenic Mice to 898.4 MHz Microwaves does not Increase Lymphoma Incidence. *Radiat Res* 158(3):357-364, 2002.

A total of 120 E μ im1 heterozygous mice and 120 wild-type mice were exposed for 1 h/day 5 days/week at each of the four exposure levels in "Ferris-wheel" exposure systems for up to 104 weeks to GSM-modulated 898.4 MHz radiation at SARs of 0.25, 1.0, 2.0 and 4.0 W/kg. In addition, 120 heterozygous and 120 wild-type mice were sham-exposed; there was also an unrestrained negative control group. Four exposure levels were used to investigate whether a dose-response effect could be detected. Independent verification confirmed that the exposures in the current study were nonthermal. There was no significant difference in the incidence of lymphomas between exposed and sham-exposed groups at any of the exposure levels. A dose-response effect was not detected. The findings showed that long-term exposures of lymphoma-prone mice to 898.4 MHz GSM radiofrequency (RF) radiation at SARs of 0.25, 1.0, 2.0 and 4.0 W/kg had no significant effects when compared to sham-irradiated animals. A previous study (Repacholi et al., *Radiat. Res.* 147, 631-640, 1997) reported that long-term exposure of lymphoma-prone mice to one exposure level of 900 MHz RF radiation significantly increased the incidence of non-lymphoblastic lymphomas when compared to sham-irradiated animals.

Valbonesi P, Franzellitti S, Piano A, Contin A, Biondi C, Fabbri E. Evaluation of HSP70 Expression and DNA Damage in Cells of a Human Trophoblast Cell Line Exposed to 1.8 GHz Amplitude-Modulated Radiofrequency Fields. *Radiat Res.* 169(3):270-279, 2008.

The aim of this study was to determine whether high-frequency electromagnetic fields (EMFs) could induce cellular effects. The human trophoblast cell line HTR-8/SVneo was used as a model to evaluate the expression of proteins (HSP70 and HSC70) and genes (HSP70A, B, C and HSC70) of the HSP70 family and the primary DNA damage response after nonthermal exposure to pulse-modulated 1817 MHz sinusoidal waves (GSM-217 Hz; 1 h; SAR of 2 W/kg). HSP70 expression was significantly enhanced by heat, which was applied as the prototypical stimulus. The HSP70A, B and C transcripts were differentially expressed under basal conditions, and they were all significantly induced above basal levels by thermal stress. Conversely, HSC70 protein and gene expression was not influenced by heat. Exposing HTR-8/SVneo cells to high-frequency EMFs did not change either HSP70 or HSC70 protein or gene expression. A significant increase in DNA strand breaks was caused by exposure to H₂O₂, which was used as a positive stimulus; however, no effect was observed after exposure of cells to high-frequency EMFs. Overall, no evidence was found that a 1-h exposure to GSM-217 Hz induced a HSP70-mediated stress response or primary DNA damage in HTR-8/SVneo cells. Nevertheless, further investigations on trophoblast cell responses after exposure to GSM signals of different types and durations are needed.

Vanderwaal RP, Cha B, Moros EG, Roti Roti JL. HSP27 phosphorylation increases after 45 degrees C or 41 degrees C heat shocks but not after non-thermal TDMA or GSM exposures. *Int J Hyperthermia.* 22(6):507-519, 2006.

Purpose: Experiments with cultured HeLa, S3 and E.A. Hy296 cells were performed to determine if exposure to acute (30 min at 45 degrees C) or chronic (2 h at 41 degrees C) heat shocks or to non-thermal exposures of radiofrequency radiation (RF) induce changes in HSP27 phosphorylation. Materials and methods: The radiofrequency (RF) exposures used in this study were 847 MHz time division multiple access modulated (TDMA) at a specific absorption rate (SAR) of 5 W kg⁻¹ for 1, 2 or 24 h or 900 MHz GSM modulated (GSM) at a SAR of 3.7 W kg⁻¹ for 1, 2 or 5 h. HSP27 phosphorylation was evaluated by resolving the various phosphorylation forms using two-dimensional gel electrophoresis measuring the relative amount of each by densitometry. Alternatively, an antibody specific for phosphorylated HSP27 was used to detect changes in HSP27 phosphorylation levels. All heat shock and RF exposure conditions were analysed simultaneously along with a matched incubator control sample. Each experiment was repeated three times. Results: Following heat shock, the degree of phosphorylation of HSP27 varied with the heat dose, with acute hyperthermia (45 degrees C) having an increased proportion of higher phosphorylated forms. Exposure of HeLa S3 cells to 5 W kg⁻¹ TDMA for 1, 2 or 24 h did not induce significant differences in the levels of HSP27 phosphorylation compared to incubator control or sham.

Exposure of E.A. Hy926 cells to 3.7 W kg⁻¹ 900 MHz GSM for 1, 2 or 5 h did not induce significant differences in the levels of HSP27 phosphorylation compared to sham exposed. Conclusions: Acute and moderate hyperthermia significantly increase HSP27 phosphorylation, but there was no significant change in the levels of HSP27 following non-thermal exposure to TDMA and GSM modulated RF radiations.

Vecchio F, Babiloni C, Ferreri F, Curcio G, Fini R, Del Percio C, Rossini PM. Mobile phone emission modulates interhemispheric functional coupling of EEG alpha rhythms. Eur J Neurosci. 25(6):1908-1913, 2007.

We tested the working hypothesis that electromagnetic fields from mobile phones (EMFs) affect interhemispheric synchronization of cerebral rhythms, an important physiological feature of information transfer into the brain. Ten subjects underwent two electroencephalographic (EEG) recordings, separated by 1 week, following a crossover double-blind paradigm in which they were exposed to a mobile phone signal (global system for mobile communications; GSM). The mobile phone was held on the left side of the subject head by a modified helmet, and orientated in the normal position for use over the ear. The microphone was orientated towards the corner of the mouth, and the antenna was near the head in the parietotemporal area. In addition, we positioned another similar phone (but without battery) on the right side of the helmet, to balance the weight and to prevent the subject localizing the side of GSM stimulation (and consequently lateralizing attention). In one session the exposure was real (GSM) while in the other it was Sham; both sessions lasted 45 min. Functional interhemispheric connectivity was modelled using the analysis of EEG spectral coherence between frontal, central and parietal electrode pairs. Individual EEG rhythms of interest were delta (about 2-4 Hz), theta (about 4-6 Hz), alpha 1 (about 6-8 Hz), alpha 2 (about 8-10 Hz) and alpha 3 (about 10-12 Hz). Results showed that, compared to Sham stimulation, GSM stimulation modulated the interhemispheric frontal and temporal coherence at alpha 2 and alpha 3 bands. The present results suggest that prolonged mobile phone emission affects not only the cortical activity but also the spread of neural synchronization conveyed by interhemispherical functional coupling of EEG rhythms.

Velizarov, S, Raskmark, P, Kwee, S, The effects of radiofrequency fields on cell proliferation are non-thermal. Bioelectrochem Bioenerg 48(1):177-180, 1999.

The number of reports on the effects induced by radiofrequency (RF) electromagnetic fields and microwave (MW) radiation in various cellular systems is still increasing. Until now no satisfactory mechanism has been proposed to explain the biological effects of these fields. One of the current theories is that heat generation by RF/MW is the cause, in spite of the fact that a great number of studies under isothermal conditions have reported significant cellular changes after exposure to RF/MW. Therefore, this study was undertaken to investigate which effect MW radiation from these fields in combination with a significant change of temperature could have on cell proliferation. The experiments were performed on the same cell line, and with the same exposure system as in a previous work [S. Kwee, P. Raskmark, Changes in cell proliferation due to environmental non-ionizing radiation: 2. Microwave radiation, Bioelectrochem. Bioenerg., 44 (1998), pp. 251-255]. The field was generated by signal simulation of the Global System for Mobile communications (GSM) of 960 MHz. Cell cultures, growing in microtiter plates, were exposed in a specially constructed chamber, a Transverse Electromagnetic (TEM) cell. The Specific Absorption Rate (SAR) value for each cell well was calculated for this exposure system. However, in this study the cells were exposed to the field at a higher or lower temperature than the temperature in the field-free incubator i.e., the temperature in the TEM cell was either 39 or 35 +/- 0.1 degrees C. The corresponding sham experiments were performed under exactly the same experimental conditions. The results showed that there was a significant change in cell proliferation in the exposed cells in comparison to the non-exposed (control) cells at both temperatures. On the other hand, no significant change in proliferation rate was found in the sham-exposed cells at both temperatures. This shows that biological effects due to RF/MW cannot be attributed only to a change of temperature. Since the RF/MW induced changes were of the same order of magnitude at both temperatures and also comparable to our previous results under isothermal conditions at 37 degrees C, cellular stress caused by electromagnetic fields could initiate the changes in cell cycle reaction rates. It is widely accepted that certain classes of heat-shock proteins are involved in these stress reactions.

Verschaeve, L., Heikkinen, P., Verheyen, G., Van Gorp, U., Boonen, F., Vander Plaetse, F., Maes, A., Kumlin, T., Maki-Paakkanen, J., Puranen, L. and Juutilainen, J. Investigation of Co-genotoxic Effects of Radiofrequency Electromagnetic Fields In Vivo. Radiat. Res. 165, 598-607, 2006.

We investigated the possible combined genotoxic effects of radiofrequency (RF) electromagnetic fields (900 MHz, amplitude modulated at 217 Hz, mobile phone signal) with the drinking water mutagen and carcinogen 3-chloro-4-(dichloromethyl)-5-hydroxy-2(5H)-furanone (MX). Female rats were exposed to RF fields for a period of 2 years for 2 h per day, 5 days per week at average whole-body specific absorption rates of 0.3 or 0.9 W/kg. MX was given in the drinking water at a concentration of 19 µg/ml. Blood samples were taken at 3, 6 and 24 months of exposure and brain and liver samples were taken at the end of the study (24 months). DNA damage was assessed in all samples using the alkaline comet assay, and micronuclei were determined in erythrocytes. We did not find significant genotoxic activity of MX in blood and liver cells. However, MX induced DNA damage in rat brain. Co-exposures to MX and RF radiation did not significantly increase the response of blood, liver and brain cells compared to MX exposure only. In conclusion, this 2-year animal study involving long-term exposures to RF radiation and MX did not provide any evidence for enhanced genotoxicity in rats exposed to RF radiation.

Von Klitzing, L, Low-frequency pulsed electromagnetic fields influence EEG of man. *Phys. Medica* 11:77-80, 1995.

New techniques using low-frequency pulsed electromagnetic fields (e.g., digital telecommunication) have raised the question for interference with the biological system of man. EEG data of man sampled under the influence of these electromagnetic fields are altered extremely in the range of alpha-activity as well as during after exposure for some hours. The biological effect is induced by field intensities lower than the given international limiting values.

Vijayalaxmi, Leal BZ, Meltz ML, Pickard WF, Bisht KS, Roti Roti JL, Straube WL, Moros EG, Cytogenetic Studies in Human Blood Lymphocytes Exposed In Vitro to Radiofrequency Radiation at a Cellular Telephone Frequency (835.62 MHz, FDMA). *Radiat Res* 155(1):113-121, 2001.

Vijayalaxmi, Pickard, W. F., Bisht, K. S., Leal, B. Z., Meltz, M. L., Roti Roti, J. L., Straube, W. L. and Moros, E. G. Cytogenetic Studies in Human Blood Lymphocytes Exposed In Vitro to Radiofrequency Radiation at a Cellular Telephone Frequency (835.62 MHz, FDMA). Freshly collected peripheral blood samples from four healthy human volunteers were diluted with RPMI 1640 tissue culture medium and exposed in sterile T-75 tissue culture flasks in vitro for 24 h to 835.62 MHz radiofrequency (RF) radiation, a frequency employed for customer-to-base station transmission of cellular telephone communications. An analog signal was used, and the access technology was frequency division multiple access (FDMA, continuous wave). A nominal net forward power of 68 W was used, and the nominal power density at the center of the exposure flask was 860 W/m². The mean specific absorption rate in the exposure flask was 4.4 or 5.0 W/kg. Aliquots of diluted blood that were sham-exposed or exposed in vitro to an acute dose of 1.50 Gy of gamma radiation were used as negative or positive controls. Immediately after the exposures, the lymphocytes were stimulated with a mitogen, phytohemagglutinin, and cultured for 48 or 72 h to determine the extent of genetic damage, as assessed from the frequencies of chromosomal aberrations and micronuclei. The extent of alteration in the kinetics of cell proliferation was determined from the mitotic indices in 48-h cultures and from the incidence of binucleate cells in 72-h cultures. The data indicated no significant differences between RF-radiation- and sham-exposed lymphocytes with respect to mitotic indices, incidence of exchange aberrations, excess fragments, binucleate cells, and micronuclei. In contrast, the response of the lymphocytes exposed to gamma radiation was significantly different from both RF-radiation- and sham-exposed cells for all of these indices. Thus, under the experimental conditions tested, there is no evidence for the induction of chromosomal aberrations and micronuclei in human blood lymphocytes exposed in vitro for 24 h to 835.62 MHz RF radiation at SARs of 4.4 or 5.0 W/kg.

Vijayalaxmi, Bisht KS, Pickard WF, Meltz ML, Roti Roti JL, Moros EG. Chromosome damage and micronucleus formation in human blood lymphocytes exposed in vitro to radiofrequency radiation at a cellular telephone frequency (847.74 MHz, CDMA). *Radiat Res* 156(4):430-432, 2001.

Peripheral blood samples collected from four healthy nonsmoking human volunteers were diluted with tissue culture medium and exposed in vitro for 24 h to 847.74 MHz radiofrequency (RF) radiation (continuous wave), a frequency employed for cellular telephone communications. A code division multiple access (CDMA) technology was used with a nominal net forward power of 75 W and a nominal power density of 950 W/m² (95 mW/cm²). The mean specific absorption rate (SAR) was 4.9 or 5.5 W/kg. Blood aliquots that were sham-exposed or exposed in vitro to an acute dose of 1.5 Gy of gamma radiation were included in the study as controls. The temperatures of the medium during RF-radiation

and sham exposures in the Radial Transmission Line facility were controlled at 37 +/- 0.3 degrees C. Immediately after the exposures, lymphocytes were cultured at 37 +/- 1 degrees C for 48 or 72 h. The extent of genetic damage was assessed from the incidence of chromosome aberrations and micronuclei. The kinetics of cell proliferation was determined from the mitotic indices in 48-h cultures and from the incidence of binucleate cells in 72-h cultures. The data indicated no significant differences between RF-radiation-exposed and sham-exposed lymphocytes with respect to mitotic indices, frequencies of exchange aberrations, excess fragments, binucleate cells, and micronuclei. The response of gamma-irradiated lymphocytes was significantly different from that of both RF-radiation-exposed and sham-exposed cells for all of these indices. Thus there was no evidence for induction of chromosome aberrations and micronuclei in human blood lymphocytes exposed in vitro for 24 h to 847.74 MHz RF radiation (CDMA) at SARs of 4.9 or 5.5 W/kg.

Vijayalaxmi, Sasser LB, Morris JE, Wilson BW, Anderson LE. Genotoxic Potential of 1.6 GHz Wireless Communication Signal: In Vivo Two-Year Bioassay. *Radiat Res* 159(4):558-564, 2003.

Timed-pregnant Fischer 344 rats (from nineteenth day of gestation) and their nursing offspring (until weaning) were exposed to a far-field 1.6 GHz Iridium wireless communication signal for 2 h/day, 7 days/week. Far-field whole-body exposures were conducted with a field intensity of 0.43 mW/cm² and whole-body average specific absorption rate (SAR) of 0.036 to 0.077 W/kg (0.10 to 0.22 W/kg in the brain). This was followed by chronic, head-only exposures of male and female offspring to a near-field 1.6 GHz signal for 2 h/day, 5 days/week, over 2 years. Near-field exposures were conducted at an SAR of 0.16 or 1.6 W/kg in the brain. Concurrent sham-exposed and cage control rats were also included in the study. At the end of 2 years, all rats were necropsied. Bone marrow smears were examined for the extent of genotoxicity, assessed from the presence of micronuclei in polychromatic erythrocytes. The results indicated that the incidence of micronuclei/2000 polychromatic erythrocytes were not significantly different between 1.6 GHz-exposed, sham-exposed and cage control rats. The group mean frequencies were 5.6 +/- 1.8 (130 rats exposed to 1.6 GHz at 0.16 W/kg SAR), 5.4 +/- 1.5 (135 rats exposed to 1.6 GHz at 1.6 W/kg SAR), 5.6 +/- 1.7 (119 sham-exposed rats), and 5.8 +/- 1.8 (100 cage control rats). In contrast, positive control rats treated with mitomycin C exhibited significantly elevated incidence of micronuclei/2000 polychromatic erythrocytes in bone marrow cells; the mean frequency was 38.2 +/- 7.0 (five rats). Thus there was no evidence for excess genotoxicity in rats that were chronically exposed to 1.6 GHz compared to sham-exposed and cage controls.

Vollrath L, Spessert R, Kratzsch T, Keiner M, Hollmann H, No short-term effects of high-frequency electromagnetic fields on the mammalian pineal gland. *Bioelectromagnetics* 18(5):376-387, 1997.

There is ample experimental evidence that changes of earth-strength static magnetic fields, pulsed magnetic fields, or alternating electric fields (60 Hz) depress the nocturnally enhanced melatonin synthesis of the pineal gland of certain mammals. No data on the effects of high-frequency electromagnetic fields on melatonin synthesis is available. In the present study, exposure to 900 MHz electromagnetic fields [0.1 to 0.6 mW/cm², approximately 0.06 to 0.36 W/kg specific absorption rate (SAR) in rats and 0.04 W/kg in Djungarian hamsters; both continuous and/or pulsed at 217 Hz, for 15 min to 6 hr at day or night had no notable short-term effect on pineal melatonin synthesis in male and female Sprague-Dawley rats and Djungarian hamsters. Pineal synaptic ribbon profile numbers (studied in rats only) were likewise not affected. The 900 MHz electromagnetic fields, unpulsed or pulsed at 217 Hz, as applied in the present study, have no short-term effect on the mammalian pineal gland.

Vorobyov V, Pesic V, Janac B, Prolic Z. Repeated exposure to low-level extremely low frequency-modulated microwaves affects baseline and scopolamine-modified electroencephalograms in freely moving rats. *Int J Radiat Biol.* 80(9):691-698, 2004.

PURPOSE: To compare in the electroencephalogram of rats the effects of scopolamine (an acetylcholine receptor antagonist) alone and after repeated exposure to low-level microwaves modulated at extremely low frequency. **MATERIALS AND METHODS:** Averaged frequency spectra (0.5-30 Hz) of the electroencephalogram were studied in freely moving rats with carbon electrodes implanted into the somatosensory cortex. The rats were repeatedly (3 days, 30 min day⁻¹) exposed to low-intensity (approximately = 0.3 mW cm⁻²) microwaves (915 MHz, 20-ms pulse duration), amplitude modulated (square-wave) at extremely low frequency (4 Hz). **RESULTS:** The exposure to extremely low frequency microwaves alone significantly enhanced the fast electroencephalographic rhythms (18-30 Hz). This effect was

observed neither in subsequent sham-exposure experiment nor in radiation-naïve animals. In the microwave-exposed rats, scopolamine (0.1 mg kg⁻¹), subcutaneously) did not cause a slowing in the electroencephalogram that was shown in non-exposed rats. A similarity between the scopolamine-induced electroencephalogram effect in the microwave-exposed rats and that of physostigmine (enhancing the acetylcholine level in the brain) in radiation-naïve animals was noted. This paradoxical phenomenon stimulates new experimentation for understanding its mechanism(s). CONCLUSIONS: The data obtained provide additional evidence that repeated low-level exposure to extremely low frequency microwaves can modify an activity of cholinergic system in the brain.

Vrijheid M, Richardson L, Armstrong BK, Auvinen A, Berg G, Carroll M, Chetrit A, Deltour I, Feychting M, Giles GG, Hours M, Iavarone I, Lagorio S, Lönn S, McBride M, Parent ME, Sadetzki S, Salminen T, Sanchez M, Schlehofer B, Schüz J, Siemiatycki J, Tynes T, Woodward A, Yamaguchi N, Cardis E. Quantifying the impact of selection bias caused by nonparticipation in a case-control study of mobile phone use. *Ann Epidemiol.* 19(1):33-41, 2009.

PURPOSE: To quantitatively assess the impact of selection bias caused by nonparticipation in a multinational case-control study of mobile phone use and brain tumor. **METHODS:** Non-response questionnaires (NRQ) were completed by a sub-set of nonparticipants. Selection bias factors were calculated based on the prevalence of mobile phone use reported by nonparticipants with NRQ data, and on scenarios of hypothetical exposure prevalence for other nonparticipants. **RESULTS:** Regular mobile phone use was reported less frequently by controls and cases who completed the NRQ (controls, 56%; cases, 50%) than by those who completed the full interview (controls, 69%; cases, 66%). This relationship was consistent across study centers, sex, and age groups. Lower education and more recent start of mobile phone use were associated with refusal to participate. Bias factors varied between 0.87 and 0.92 in the most plausible scenarios. **CONCLUSIONS:** Refusal to participate in brain tumor case-control studies seems to be related to less prevalent use of mobile phones, and this could result in a downward bias of around 10% in odds ratios for regular mobile phone use. The use of simple selection bias estimation methods in case-control studies can give important insights into the extent of any bias, even when nonparticipant information is incomplete.

Wagner, P, Roschke, J, Mann, K, Hiller, W, Frank, C, Human sleep under the influence of pulsed radiofrequency electromagnetic fields: a polysomnographic study using standardized conditions. *Bioelectromagnetics* 19(3):199-202, 1998.

To investigate the influence of radiofrequency electromagnetic fields (EMFs) of cellular phone GSM signals on human sleep electroencephalographic (EEG) pattern, all-night polysomnographies of 24 healthy male subjects were recorded, both with and without exposure to a circular polarized EMF (900 MHz, pulsed with a frequency of 217 Hz, pulse width 577 micros, power flux density 0.2 W/m². Suppression of rapid eye movement (REM) sleep as well as a sleep-inducing effect under field exposure did not reach statistical significance, so that previous results indicating alterations of these sleep parameters could not be replicated. Spectral power analysis also did not reveal any alterations of the EEG rhythms during EMF exposure. The failure to confirm our previous results might be due to dose-dependent effects of the EMF on the human sleep profile.

Wagner P, Roschke J, Mann K, Fell J, Hiller W, Frank C, Grozinger M, Human sleep EEG under the influence of pulsed radio frequency electromagnetic fields. results from polysomnographies using submaximal high power flux densities. *Neuropsychobiology* 42(4):207-212, 2000.

Former exploratory investigations of sleep alterations due to global system for mobile communications (GSM) signals have shown a hypnotic and REM-suppressive effect under field exposure. This effect was observed in a first study using a power flux density of 0.5 W/m², and the same trend occurred in a second study with a power flux density of 0.2 W/m². For the present study, we applied a submaximal power flux density of 50 W/m². To investigate putative effects of radio frequency electromagnetic fields (EMFs) of cellular GSM phones on human sleep EEG pattern, all-night polysomnographies of 20 healthy male subjects both with and without exposure to a circularly polarized EMF (900 MHz, pulsed with a frequency of 217 Hz, pulse duration 577 &mgr;s) were recorded. The results showed no significant effect of the field application either on conventional sleep parameters or on sleep EEG power spectra.

Walsh SP, White KM, Hyde MK, Watson B. Dialling and driving: factors influencing intentions to use a mobile phone while driving. *Accid Anal Prev.* 40(6):1893-1900, 2008.

Despite being identified as an unsafe (and, in some jurisdictions, illegal) driving practice, the psychological factors underlying people's decision to use their mobile phone while driving have received little attention. The present study utilised the theory of planned behaviour (TPB) to examine the role of attitudes, norms, control factors, and risk perceptions, in predicting people's intentions to use their mobile phone while driving. We examined the predictors of intentions to use a mobile phone while driving in general, and for calling and text messaging in 4 scenarios differing in descriptions of vehicle speed and time pressure. There was some support for the TPB given that attitudes consistently predicted intentions to drive while using a mobile phone and that pressure from significant others (norms) determined some phone use while driving intentions, although less support was found for the role of perceptions of control. Risk was not generally predictive of safer driving intentions. These findings indicate that different factors influence each form of mobile phone use while driving and, hence, a multi-strategy approach is likely to be required to address the issue.

Baohong Wang, Jiliang H, Lifen J, Deqiang L, Wei Z, Jianlin L, Hongping D. Studying the synergistic damage effects induced by 1.8GHz radiofrequency field radiation (RFR) with four chemical mutagens on human lymphocyte DNA using comet assay in vitro. *Mutat Res.* 2005 May 31; [Epub ahead of print]

The aim of this investigation was to study the synergistic DNA damage effects in human lymphocytes induced by 1.8GHz radiofrequency field radiation (RFR, SAR of 3W/kg) with four chemical mutagens, i.e. mitomycin C (MMC, DNA crosslinker), bleomycin (BLM, radiomimetic agent), methyl methanesulfonate (MMS, alkylating agent), and 4-nitroquinoline-1-oxide (4NQO, UV-mimetic agent). The DNA damage of lymphocytes exposed to RFR and/or with chemical mutagens was detected at two incubation time (0 or 21h) after treatment with comet assay in vitro. Three combinative exposure ways were used. Cells were exposed to RFR and chemical mutagens for 2 and 3h, respectively. Tail length (TL) and tail moment (TM) were utilized as DNA damage indexes. The results showed no difference of DNA damage indexes between RFR group and control group at 0 and 21h incubation after exposure ($P>0.05$). There were significant difference of DNA damage indexes between MMC group and RFR+MMC co-exposure group at 0 and 21h incubation after treatment ($P<0.01$). Also the significant difference of DNA damage indexes between 4NQO group and RFR+4NQO co-exposure group at 0 and 21h incubation after treatment was observed ($P<0.05$ or $P<0.01$). The DNA damage in RFR+BLM co-exposure groups and RFR+MMS co-exposure groups was not significantly increased, as compared with corresponding BLM and MMS groups ($P>0.05$). The experimental results indicated 1.8GHz RFR (SAR, 3W/kg) for 2h did not induce the human lymphocyte DNA damage effects in vitro, but could enhance the human lymphocyte DNA damage effects induced by MMC and 4NQO. The synergistic DNA damage effects of 1.8GHz RFR with BLM or MMS were not obvious.

Wang Q, Cao ZJ, Bai XT. [Effect of 900 MHz electromagnetic fields on the expression of GABA receptor of cerebral cortical neurons in postnatal rats] *Wei Sheng Yan Jiu.* 34(5):546-548, 2005.

OBJECTIVE: To investigate the effects of 900 MHz microwave electromagnetic fields (EMF) on the expression of neurotransmitter GABA receptor of cerebral cortical neurons in postnatal rats. **METHODS:** Neurons were exposed to 900 MHz continuous microwave EMF (SAR = 1.15 - 3.22mW/g) for 2 hours per day in 6 consecutive days and for 12 hours at one time. GABA receptor was chosen to be the biological end. **RESULTS:** Significant changes had been observed in exposed neurons in the expression of GABA receptor. ($P < 0.01$). **CONCLUSION:** The expression of GABA receptor of neurons were significantly regulated by 900 MHz microwave, and a power "window" effect was observed in the exposed neurons.

Wang LL, Chen GD, Lu DQ, Chiang H, Xu ZP. [Global gene response to GSM 1800 MHz radiofrequency electromagnetic field in MCF-7 cells.] *Zhonghua Yu Fang Yi Xue Za Zhi.* 40(3):159-163, 2006.

[Article in Chinese]

OBJECTIVE: To investigate whether GSM 1800 MHz radiofrequency electromagnetic field (RF EMF) can change the gene expression profile in MCF-7 cells and to screen RF EMF responsive genes. **METHODS:** Subcultured MCF-7 cells were intermittently (5-minute fields on/10-minute fields off) exposed or sham-exposed to GSM 1800 MHz RF EMF,

which was modulated by 217 Hz EMF, for 24 hours at an average specific absorption rate (SAR) of 2.0 W/kg or 3.5 W/kg. Immediately after RF EMF exposure or sham-exposure, total RNA was isolated from MCF-7 cells and then purified. Affymetrix Human Genome U133A Genechip was applied to examine the change of gene expression profile according to the manufacturer's instruction. Data was analyzed by Affymetrix Microarray Suite 5.0 (MAS 5.0) and Affymetrix Data Mining Tool 3.0 (DMT 3.0). Quantitative reverse transcription polymerase chain reaction (RT-PCR) was used to validate the differentially expressed genes identified by Genechip analysis. RESULTS: A small number of differential expression genes were found in each comparison after RF EMF exposure. Through reproducible and consistent analysis, no gene or five up-regulated genes were screened out after exposure to RF EMF at SAR of 2.0 W/kg or 3.5 W/kg, respectively. However, these five genes could not be further confirmed by RT-PCR. CONCLUSION: The present study did not provide clear evidence that RF EMF exposure might distinctly change the gene expression profile in MCF-7 cells under current experimental conditions, implying that the exposure might not affect the MCF-7 cell physiology, or this cell line might be less sensitive to the RF EMF exposure.

Warren HG, Prevatt AA, Daly KA, Antonelli PJ. Cellular telephone use and risk of intratemporal facial nerve tumor. *Laryngoscope* 113(4):663-667, 2003.

OBJECTIVES/HYPOTHESIS Microwave radiation exposure from cellular telephone use has been implicated in the development of intracranial tumors. The intratemporal facial nerve (IFN) is exposed to higher levels of cellular telephone radiation than intracranial tissues. The purpose of the study was to determine whether cellular telephone use is associated with an increased risk of IFN tumors. **STUDY DESIGN** Case-control using a structured telephone survey at an academic, tertiary-care referral center. **METHODS** Patients with IFN tumors (n = 18) were case-matched with patients treated for acoustic neuroma (n = 51), rhinosinusitis (n = 72), and dysphonia or gastroesophageal reflux disease (n = 69). Risk of facial nerve tumorigenesis was compared by extent of cellular telephone use and other risk factors. **RESULTS** The odds ratio of developing an IFN tumor was 0.6 (95% CI, 0.2-1.9) with any handheld cellular telephone use and 0.4 (95% CI, 0.1-2.1) with regular cellular telephone use. No factors were associated with an increased risk for IFN tumor development. **CONCLUSIONS** Regular cellular telephone use does not appear to be associated with a higher risk of IFN tumor development. The short duration of widespread cellular telephone use precludes definite exclusion as a risk for IFN tumor development.

Wdowiak A, Wdowiak L, Wiktor H. Evaluation of the effect of using mobile phones on male fertility. *Ann Agric Environ Med.* 14(1):169-172, 2007.

The problem of the lack of offspring is a phenomenon concerning approximately 15% of married couples in Poland. Infertility is defined as inability to conceive after a year of sexual intercourse without the use of contraceptives. In half of the cases the causative factor is the male. Males are exposed to the effect of various environmental factors, which may decrease their reproductive capabilities. A decrease in male fertility is a phenomenon which occurs within years, which may suggest that one of the reasons for the decrease in semen parameters is the effect of the development of techniques in the surrounding environment. A hazardous effect on male fertility may be manifested by a decrease in the amount of sperm cells, disorders in their mobility, as well as structure. The causative agents may be chemical substances, ionizing radiation, stress, as well as electromagnetic waves. The objective of the study was the determination of the effect of the usage of cellular phones on the fertility of males subjected to marital infertility therapy. The following groups were selected from among 304 males covered by the study: Group A: 99 patients who did not use mobile phones, Group B: 157 males who have used GSM equipment sporadically for the period of 1-2 years, and Group C: 48 people who have been regularly using mobile phone for more than 2 years. In the analysis of the effect of GSM equipment on the semen it was noted that an increase in the percentage of sperm cells of abnormal morphology is associated with the duration of exposure to the waves emitted by the GSM phone. It was also confirmed that a decrease in the percentage of sperm cells in vital progressing motility in the semen is correlated with the frequency of using mobile phones.

Weisbrot D, Lin H, Ye L, Blank M, Goodman R. Effects of mobile phone radiation on reproduction and development in *Drosophila melanogaster*. *J Cell Biochem* 89(1):48-55, 2003.

In this report we examined the effects of a discontinuous radio frequency (RF) signal produced by a GSM multiband mobile phone (900/1,900 MHz; SAR approximately 1.4 W/kg) on *Drosophila melanogaster*, during the 10-day

developmental period from egg laying through pupation. As found earlier with low frequency exposures, the non-thermal radiation from the GSM mobile phone increased numbers of offspring, elevated hsp70 levels, increased serum response element (SRE) DNA-binding and induced the phosphorylation of the nuclear transcription factor, ELK-1. The rapid induction of hsp70 within minutes, by a non-thermal stress, together with identified components of signal transduction pathways, provide sensitive and reliable biomarkers that could serve as the basis for realistic mobile phone safety guidelines.

Whitehead TD, Brownstein BH, Parry JJ, Thompson D, Cha BA, Moros EG, Rogers BE, Roti Roti JL. Expression of the Proto-oncogene Fos after Exposure to Radiofrequency Radiation Relevant to Wireless Communications. *Radiat Res.* 164(4):420-430, 2005.

In this study the expression levels of the proto-oncogene Fos were measured after exposure to radiofrequency (RF) radiation at two relatively high specific absorption rates (SARs) of 5 and 10 W/kg for three types of modulated signals: 847.74 MHz code division multiple access (CDMA), 835.62 MHz frequency division multiple access (FDMA), and 836.55 MHz time division multiple access (TDMA). This work was undertaken to confirm a previous report by Goswami et al. (*Radiat. Res.* 151, 300-309, 1999) that CDMA and FDMA radiation caused small but statistically significant increases in Fos levels as cells entered plateau phase during exposure. No effects on Myc or Jun levels were observed in that study. Therefore, in the present study, analyses were restricted to Fos expression during the transition from exponential growth to plateau phase. Fos expression was measured using the real-time polymerase chain reaction (RT-PCR) technique. Serum-stimulated C3H 10T(1/2) cells were used as a positive control for Fos expression. Possible influences of final cell number or pH variability on Fos expression were evaluated. Expression of Fos mRNA in C3H 10T(1/2) cells was not significantly different from that found after sham exposure at either SAR level for any signal modulation. Therefore, the results of Goswami et al. could not be confirmed.

Whitehead TD, Moros EG, Brownstein BH, Roti Roti JL Gene expression does not change significantly in C3H 10T(1/2) cells after exposure to 847.74 CDMA or 835.62 FDMA radiofrequency radiation. *Radiat Res.* 165(6):626-635, 2006.

In vitro experiments with C3H 10T(1/2) mouse cells were performed to determine whether Frequency Division Multiple Access (FDMA) or Code Division Multiple Access (CDMA) modulated radiofrequency (RF) radiations induce changes in gene expression. After the cells were exposed to either modulation for 24 h at a specific absorption rate (SAR) of 5 W/kg, RNA was extracted from both exposed and sham-exposed cells for gene expression analysis. As a positive control, cells were exposed to 0.68 Gy of X rays and gene expression was evaluated 4 h after exposure. Gene expression was evaluated using the Affymetrix U74Av2 GeneChip to detect changes in mRNA levels. Each exposure condition was repeated three times. The GeneChip data were analyzed using a two-tailed t test, and the expected number of false positives was estimated from t tests on 20 permutations of the six sham RF-field-exposed samples. For the X-ray-treated samples, there were more than 90 probe sets with expression changes greater than 1.3-fold beyond the number of expected false positives. Approximately one-third of these genes had previously been reported in the literature as being responsive to radiation. In contrast, for both CDMA and FDMA radiation, the number of probe sets with an expression change greater than 1.3-fold was less than or equal to the expected number of false positives. Thus the 24-h exposures to FDMA or CDMA RF radiation at 5 W/kg had no statistically significant effect on gene expression.

Whitehead TD, Moros EG, Brownstein BH, Roti Roti JL. The number of genes changing expression after chronic exposure to Code Division Multiple Access or Frequency DMA radiofrequency radiation does not exceed the false-positive rate. *Proteomics.* 6(17):4739-4744, 2006.

Experiments with cultured C3H 10T 1/2 cells were performed to determine if exposure to cell phone radiofrequency (RF) radiations induce changes in gene expression. Following a 24 h exposure of 5 W/kg specific adsorption rate, RNA was extracted from the exposed and sham control cells for microarray analysis on Affymetrix U74Av2 Genechips. Cells exposed to 0.68 Gy of X-rays with a 4-h recovery were used as positive controls. The number of gene expression changes induced by RF radiation was not greater than the number of false positives expected based on a sham versus sham comparison. In contrast, the X-irradiated samples showed higher numbers of probe sets changing expression level than in the sham versus sham comparison.

Wiholm C, Lowden A, Kuster N, Hillert L, Arnetz BB, Akerstedt T, Moffat SD Mobile phone exposure and spatial memory. *Bioelectromagnetics*. 2008 Sep 15. [Epub ahead of print]

Radiofrequency (RF) emission during mobile phone use has been suggested to impair cognitive functions, that is, working memory. This study investigated the effects of a 2×10^5 h RF exposure (884 MHz) on spatial memory and learning, using a double-blind repeated measures design. The exposure was designed to mimic that experienced during a real-life mobile phone conversation. The design maximized the exposure to the left hemisphere. The average exposure was peak spatial specific absorption rate (psSAR_{10g}) of 1.4 W/kg. The primary outcome measure was a "virtual" spatial navigation task modeled after the commonly used and validated Morris Water Maze. The distance traveled on each trial and the amount of improvement across trials (i.e., learning) were used as dependent variables. The participants were daily mobile phone users, with and without symptoms attributed to regular mobile phone use. Results revealed a main effect of RF exposure and a significant RF exposure by group effect on distance traveled during the trials. The symptomatic group improved their performance during RF exposure while there was no such effect in the non-symptomatic group. Until this new finding is further investigated, we can only speculate about the cause.

Wilen J, Sandstrom M, Hansson Mild K. Subjective symptoms among mobile phone users-A consequence of absorption of radiofrequency fields? *Bioelectromagnetics* 24(3):152-159, 2003.

In a previous epidemiological study, where we studied the prevalence of subjective symptoms among mobile phone (MP) users, we found as an interesting side finding that the prevalence of many of the subjective symptoms increased with increasing calling time and number of calls per day. In this extrapolative study, we have selected 2402 people from the epidemiological study who used any of the four most common GSM MP. We used the information about the prevalence of symptoms, calling time per day, and number of calls per day and combined it with measurements of the Specific Absorption Rate (SAR). We defined three volumes in the head and measured the maximum SAR averaged over a cube of 1 g tissue (SAR(1g)) in each volume. Two new exposure parameters Specific Absorption per Day (SAD) and Specific Absorption per Call (SAC) have been devised and are obtained as combinations of SAR, calling time per day, and number of calls per day, respectively. The results indicates that SAR values >0.5 W/kg may be an important factor for the prevalence of some of the symptoms, especially in combination with long calling times per day.

Wilen J, Johansson A, Kalezić N, Lyskov E, Sandstrom M. Psychophysiological tests and provocation of subjects with mobile phone related symptoms. *Bioelectromagnetics*. 2005 Nov 22; [Epub ahead of print]

The aim of the present study was to investigate the effect of exposure to a mobile phone-like radiofrequency (RF) electromagnetic field on persons experiencing subjective symptoms when using mobile phones (MP). Twenty subjects with MP-related symptoms were recruited and matched with 20 controls without MP-related symptoms. Each subject participated in two experimental sessions, one with true exposure and one with sham exposure, in random order. In the true exposure condition, the test subjects were exposed for 30 min to an RF field generating a maximum SAR(1g) in the head of 1 W/kg through an indoor base station antenna attached to a 900 MHz GSM MP. The following physiological and cognitive parameters were measured during the experiment: heart rate and heart rate variability (HRV), respiration, local blood flow, electrodermal activity, critical flicker fusion threshold (CFFT), short-term memory, and reaction time. No significant differences related to RF exposure conditions were detected. Also no differences in baseline data were found between subject groups, except for the reaction time, which was significantly longer among the cases than among the controls the first time the test was performed. This difference disappeared when the test was repeated. However, the cases differed significantly from the controls with respect to HRV as measured in the frequency domain. The cases displayed a shift in low/high frequency ratio towards a sympathetic dominance in the autonomous nervous system during the CFFT and memory tests, regardless of exposure condition. This might be interpreted as a sign of differences in the autonomous nervous system regulation between persons with MP related subjective symptoms and persons with no such symptoms.

Wolf R, Wolf D. Increased incidence of cancer near a cell-phone transmitter station. *Inter J Cancer Prev* 1(2):123-128, 2004.

Significant concern has been raised about possible health effects from exposure to radiofrequency (RF) electromagnetic fields, especially after the rapid introduction of mobile telecommunication systems. Parents are especially concerned with the possibility that children might develop cancer after exposure to the RF emissions from mobile telephone base stations erected in or near schools. The few epidemiologic studies that did report on cancer incidence in relation to RF radiation have generally presented negative or inconsistent results, and thus emphasized the need for more studies that should investigate cohorts with high RF exposure for changes in cancer incidence. The aim of this study is to investigate whether there is an increased cancer incidence in populations, living in a small area, and exposed to RF radiation from a cell-phone transmitter station.

This is an epidemiologic assessment, to determine whether the incidence of cancer cases among individuals exposed to a cell-phone transmitter station is different from that expected in Israel, in Netanya, or as compared to people who lived in a nearby area. Participants are people (n=622) living in the area near a cell-phone transmitter station for 3-7 years who were patients of one health clinic (of DW). The exposure began 1 year before the start of the study when the station first came into service. A second cohort of individuals (n=1222) who get their medical services in a clinic located nearby with very closely matched, environment, workplace and occupational characteristics was used for comparison.

In the area of exposure (area A) eight cases of different kinds of cancer were diagnosed in a period of only one year. This rate of cancers was compared both with the rate of 31 cases per 10,000 per year in the general population and the 2/1222 rate recorded in the nearby clinic (area B). Relative cancer rates for female were 10.5 for area A, 0.6 for area B and 1 for the whole town of Netanya. Cancer incidence of women in area A was thus significantly higher ($p < 0.0001$) compared with that of area B and the whole city. A comparison of the relative risk revealed that there were 4.15 times more cases in area A than in the entire population.

The study indicates an association between increased incidence of cancer and living in proximity to a cell-phone transmitter station.

Wolke S, Neibig U, Elsner R, Gollnick F, Meyer R, Calcium homeostasis of isolated heart muscle cells exposed to pulsed high-frequency electromagnetic fields. *Bioelectromagnetics* 17(2):144-153, 1996.

The intracellular calcium concentration ($[Ca^{2+}]_i$) of isolated ventricular cardiac myocytes of the guinea pig was measured during the application of pulsed high-frequency electromagnetic fields. The high-frequency fields were applied in a transverse electromagnetic cell designed to allow microscopic observation of the myocytes during the presence of the high-frequency fields. The $[Ca^{2+}]_i$ was measured as fura-2 fluorescence by means of digital image analysis. Both the carrier frequency and the square-wave pulse-modulation pattern were varied during the experiments (carrier frequencies: 900, 1,300, and 1,800 MHz pulse modulated at 217 Hz with 14 percent duty cycle; pulsation pattern at 900 MHz: continuous wave, 16 Hz, and 50 Hz modulation with 50 percent duty cycle and 30 kHz modulation with 80 percent duty cycle). The mean specific absorption rate (SAR) values in the solution were within one order of magnitude of **1 mW/kg**. They varied depending on the applied carrier frequency and pulse pattern. The experiments were designed in three phases: 500 s of sham exposure, followed by 500 s of field exposure, then chemical stimulation without field. The chemical stimulation (K^+ - depolarization) indicated the viability of the cells. The K^+ depolarization yielded a significant increase in $[Ca^{2+}]_i$. Significant differences between sham exposure and high-frequency field exposure were not found except when a very small but statistically significant difference was detected in the case of 900 MHz/50 Hz. However, this small difference was not regarded as a relevant effect of the exposure.

Wood A, Loughran S, Stough C, Does evening exposure to mobile phone radiation affect subsequent melatonin production? *Int. J. Rad. Biol* 82:69-76, 2006.

Purpose: To test whether exposure to the emissions from a digital mobile phone handset prior to sleep alters the secretion of melatonin. Materials and methods: In a double-blind cross-over design, 55 adult volunteers were both actively exposed or sham-exposed (in random order on successive Sunday nights) to mobile phone emissions for 30 min (0.25 W average power). Urine collection occurred immediately prior to retiring to bed and on rising the next morning. Melatonin output was estimated from principal metabolite concentrations (6-sulphatoxymelatonin (aMT6s) via radioimmunoassay), urine volumes and creatinine concentrations. Results: Total melatonin metabolite output (concentration \times urine volume) was unchanged between the two exposure conditions (active $14.1 \pm 1.1 \mu\text{g}$; sham $14.6 \pm 1.3 \mu\text{g}$). The pre- and post-bedtime outputs considered separately were also not significantly different, although the pre-bedtime value was less for active versus sham exposure. When melatonin metabolite output was estimated from the ratio of aMT6s to creatinine concentrations, the pre-bedtime value was significantly less ($p = 0.037$) for active compared to sham. Examination of

individual responses is suggestive of a small group of 'responders'. Conclusions: Total nighttime melatonin output is unchanged by mobile phone handset emissions, but there could be an effect on melatonin onset time.

Wu W, Yao K, Wang KJ, Lu DQ, He JL, Xu LH, Sun WJ. [Blocking 1800 MHz mobile phone radiation-induced reactive oxygen species production and DNA damage in lens epithelial cells by noise magnetic fields.] *Zhejiang Da Xue Xue Bao Yi Xue Ban.* 37(1):34-38, 2008.

[Article in Chinese]

OBJECTIVE: To investigate whether the exposure to the electromagnetic noise can block reactive oxygen species (ROS) production and DNA damage of lens epithelial cells induced by 1800 MHz mobile phone radiation. **METHODS:** The DCFH-DA method and comet assay were used respectively to detect the intracellular ROS and DNA damage of cultured human lens epithelial cells induced by 4 W/kg 1800 MHz mobile phone radiation or/and 2microT electromagnetic noise for 24 h intermittently. **RESULT:** 1800 MHz mobile phone radiation at 4 W/kg for 24 h increased intracellular ROS and DNA damage significantly ($P<0.05$). However, the ROS level and DNA damage of mobile phone radiation plus noise group were not significant enhanced ($P>0.05$) as compared to sham exposure group. **Conclusion:** Electromagnetic noise can block intracellular ROS production and DNA damage of human lens epithelial cells induced by 1800 MHz mobile phone radiation.

Yao K, Wu W, Wang K, Ni S, Ye P, Yu Y, Ye J, Sun L. Electromagnetic noise inhibits radiofrequency radiation-induced DNA damage and reactive oxygen species increase in human lens epithelial cells. *Mol Vis.* 14:964-969, 2008.

PURPOSE: The goal of this study was to investigate whether superposing of electromagnetic noise could block or attenuate DNA damage and intracellular reactive oxygen species (ROS) increase of cultured human lens epithelial cells (HLECs) induced by acute exposure to 1.8 GHz radiofrequency field (RF) of the Global System for Mobile Communications (GSM). **METHODS:** An sXc-1800 RF exposure system was used to produce a GSM signal at 1.8 GHz (217 Hz amplitude-modulated) with the specific absorption rate (SAR) of 1, 2, 3, and 4 W/kg. After 2 h of intermittent exposure, the ROS level was assessed by the fluorescent probe, 2',7'-dichlorodihydrofluorescein diacetate (DCFH-DA). DNA damage to HLECs was examined by alkaline comet assay and the phosphorylated form of histone variant H2AX (gammaH2AX) foci formation assay. **RESULTS:** After exposure to 1.8 GHz RF for 2 h, HLECs exhibited significant intracellular ROS increase in the 2, 3, and 4 W/kg groups. RF radiation at the SAR of 3 W/kg and 4 W/kg could induce significant DNA damage, examined by alkaline comet assay, which was used to detect mainly single strand breaks (SSBs), while no statistical difference in double strand breaks (DSBs), evaluated by gammaH2AX foci, was found between RF exposure (SAR: 3 and 4 W/kg) and sham exposure groups. When RF was superposed with 2 muT electromagnetic noise could block RF-induced ROS increase and DNA damage. **CONCLUSIONS:** DNA damage induced by 1.8 GHz radiofrequency field for 2 h, which was mainly SSBs, may be associated with the increased ROS production. Electromagnetic noise could block RF-induced ROS formation and DNA damage.

Yu Y, Yao K, Wu W, Wang K, Chen G, Lu D. Effects of exposure to 1.8 GHz radiofrequency field on the expression of Hsps and phosphorylation of MAPKs in human lens epithelial cells. *Cell Res.* 18(12):1233-1235, 2008. (No abstract available)

Last sentence of discussion:

“Our results suggest that exposure to RF of wireless communications can induce expression of Hsp27 and Hsp70 and the activation of ERK1/2 and JNK1/2 in human LECs. The induction of Hsp27 and Hsp70, by a non-thermal stress, together with the activation of signal transduction pathways, provides reliable and sensitive biomarkers that could serve as the basis for improved mobile phone safety guidelines.”

Yurekli AI, Ozkan M, Kalkan T, Saybasili H, Tuncel H, Atukeren P, Gumustas K, Seker S. GSM base station electromagnetic radiation and oxidative stress in rats. *Electromagn Biol Med.* 25(3):177-188, 2006.

The ever increasing use of cellular phones and the increasing number of associated base stations are becoming a widespread source of nonionizing electromagnetic radiation. Some biological effects are likely to occur even at low-level EM fields. In this study, a gigahertz transverse electromagnetic (GTEM) cell was used as an exposure environment for plane wave conditions of far-field free space EM field propagation at the GSM base transceiver station (BTS) frequency of 945 MHz, and effects on oxidative stress in rats were investigated. When EM fields at a power density of 3.67 W/m² (specific absorption rate = 11.3 mW/kg), which is well below current exposure limits, were applied, MDA (malondialdehyde) level was found to increase and GSH (reduced glutathione) concentration was found to decrease significantly ($p < 0.0001$). Additionally, there was a less significant ($p = 0.0190$) increase in SOD (superoxide dismutase) activity under EM exposure.

Xu S, Ning W, Xu Z, Zhou S, Chiang H, Luo J. Chronic exposure to GSM 1800-MHz microwaves reduces excitatory synaptic activity in cultured hippocampal neurons. Neurosci Lett. 2006 Jan 25; [Epub ahead of print]

The world wide proliferation of mobile phones raises the concern about the health effects of 1800-MHz microwaves on the brain. The present study assesses the effects of microwave exposure on the function of cultured hippocampal neurons of rats using whole cell patch-clamp analysis combined with immunocytochemistry. We showed that chronic exposure (15min per day for 8 days) to Global System for Mobile Communication (GSM) 1800-MHz microwaves at specific absorption rate (SAR) of 2.4W/kg induced a selective decrease in the amplitude of alpha-amino-3-hydroxy-5-methyl-4-soxazole propionic acid (AMPA) miniature excitatory postsynaptic currents (mEPSCs), whereas the frequency of AMPA mEPSCs and the amplitude of N-methyl-d-aspartate (NMDA) mEPSCs did not change. Furthermore, the GSM microwave treatment decreased the expression of postsynaptic density 95 (PSD95) in cultured neurons. Our results indicated that 2.4W/kg GSM 1800-MHz microwaves may reduce excitatory synaptic activity and the number of excitatory synapses in cultured rat hippocampal neurons.

Yadav AS, Sharma MK. Increased frequency of micronucleated exfoliated cells among humans exposed in vivo to mobile telephone radiations. Mutat Res. 650(2):175-180, 2008.

The health concerns have been raised following the enormous increase in the use of wireless mobile telephones throughout the world. This investigation had been taken, with the motive to find out whether mobile phone radiations cause any in vivo effects on the frequency of micronucleated exfoliated cells in the exposed subjects. A total of 109 subjects including 85 regular mobile phone users (exposed) and 24 non-users (controls) had participated in this study. Exfoliated cells were obtained by swabbing the buccal-mucosa from exposed as well as sex-age-matched controls. One thousand exfoliated cells were screened from each individual for nuclear anomalies including micronuclei (MN), karyolysis (KL), karyorrhexis (KH), broken egg (BE) and binucleated (BN) cells. The average daily duration of exposure to mobile phone radiations is 61.26min with an overall average duration of exposure in term of years is 2.35 years in exposed subjects along with the 9.84+/-0.745 micronucleated cells (MNCs) and 10.72+/-0.889 total micronuclei (TMN) as compared to zero duration of exposure along with average 3.75+/-0.774 MNC and 4.00+/-0.808 TMN in controls. The means are significantly different in case of MNC and TMN at 0.01% level of significance. The mean of KL in controls is 13.17+/-2.750 and in exposed subjects is 13.06+/-1.793. The value of means of KH in exposed subjects (1.84+/-0.432) is slightly higher than in controls (1.42+/-0.737). Mean frequency of broken egg is found to be more in exposed subjects (0.65+/-0.276) as compared to controls (0.50+/-0.217). Frequency of presence of more than one nucleus in a cell (binucleated) is also higher in exposed (2.72+/-0.374) in comparison to controls (0.67+/-0.231). Although there is a slight increase in mean frequency of KH, BE and BN in exposed subjects but the difference is not found statistically significant. Correlation between 0-1, 1-2, 2-3 and 3-4 years of exposure and the frequency of MNC and TMN has been calculated and found to be positively correlated.

Yamaguchi H, Tsurita G, Ueno S, Watanabe S, Wake K, Taki M, Nagawa H. 1439 MHz pulsed TDMA fields affect performance of rats in a T-maze task only when body temperature is elevated. Bioelectromagnetics 24(4):223-230, 2003.

This study sought to clarify the effects of exposure to electromagnetic waves (EMW) used in cellular phones on learning and memory processes. Sprague-Dawley rats were exposed for either 1 h daily for 4 days or for 4 weeks to a pulsed 1439

MHz time division multiple access (TDMA) field in a carousel type exposure system. At the brain, average specific absorption rate (SAR) was 7.5 W/kg, and the whole body average SAR was 1.7 W/kg. Other subjects were exposed at the brain average SAR of 25 W/kg and the whole body average SAR of 5.7 W/kg for 45 min daily for 4 days. Learning and memory were evaluated by reversal learning in a food rewarded T-maze, in which rats learned the location of food (right or left) by using environmental cues. The animals exposed to EMW with the brain average SAR of 25 W/kg for 4 days showed statistically significant decreases in the transition in number of correct choices in the reversal task, compared to sham exposed or cage control animals. However, rats exposed to the brain average SAR of 7.5 W/kg for either 4 days or for 4 weeks showed no T-maze performance impairments. Intraperitoneal temperatures, as measured by a fiber optic thermometer, increased in the rats exposed to the brain average SAR of 25 W/kg but remained the same for the brain average SAR of 7.5 W/kg. The SAR of a standard cellular phone is restricted to a maximum of 2 W/kg averaged over 10 g tissue. These results suggest that the exposure to a TDMA field at levels about four times stronger than emitted by cellular phones does not affect the learning and memory processes when there are no thermal effects.

Yan JG, Agresti M, Bruce T, Yan YH, Granlund A, Matloub HS. Effects of cellular phone emissions on sperm motility in rats. *Fertil Steril*. 2007 Jul 10; [Epub ahead of print]

OBJECTIVE: To evaluate the effects of cellular phone emissions on rat sperm cells. DESIGN: Classic experimental. SETTING: Animal research laboratory. SUBJECTS: Sixteen 3-month-old male Sprague-Dawley rats, weighing 250-300 g. INTERVENTION(S): Rats in the experimental group were exposed to two 3-hour periods of daily cellular phone emissions for 18 weeks; sperm samples were then collected for evaluation. MAIN OUTCOME MEASURE(S): Evaluation of sperm motility, sperm cell morphology, total sperm cell number, and mRNA levels for two cell surface adhesion proteins. RESULT(S): Rats exposed to 6 hours of daily cellular phone emissions for 18 weeks exhibited a significantly higher incidence of sperm cell death than control group rats through chi-squared analysis. In addition, abnormal clumping of sperm cells was present in rats exposed to cellular phone emissions and was not present in control group rats. CONCLUSION(S): These results suggest that carrying cell phones near reproductive organs could negatively affect male fertility.

Yariktas M, Doner F, Ozguner F, Gokalp O, Dogru H, Delibas N. Nitric oxide level in the nasal and sinus mucosa after exposure to electromagnetic field. *Otolaryngol Head Neck Surg*. 132(5):713-716, 2005.

OBJECTIVE: The purpose of this study was to examine the changes in nitric oxide (NO) level in the nasal and paranasal sinus mucosa after exposure radiofrequency electromagnetic fields (EMF). STUDY DESIGN AND SETTING: Thirty male Sprague-Dawley rats were randomly grouped as follows: EMF group (group I; n, 10), EMF group in which melatonin received (group II; n, 10) and the control (sham operated) group (group III; n, 10). Groups I and II were exposed to a 900 MHz. Oral melatonin was given in group II. Control rats (group III) were also placed in the tube as the exposure groups, but without exposure to EMF. At the end of 2 weeks, the rats were sacrificed, and the nasal and paranasal sinus mucosa dissected. NO was measured in nasal and paranasal mucosa. RESULTS: The nasal and paranasal sinus mucosa NO levels of group I were significantly higher than those of the control group (group III) ($P < 0.05$). However, there was no statistically significant difference between group II and the control group (group III) regarding NO output ($P > 0.05$). CONCLUSION: Exposure to EMF released by mobile phones (900 MHz) increase NO levels in the sinus and nasal mucosa. SIGNIFICANCE: Increased NO levels may act as a defense mechanism and presumably related to tissue damage. In addition, melatonin may have beneficial effect to prevent these changes in the mucosa.

Yu D, Shen Y, Kuster N, Fu Y, Chiang H. Effects of 900 MHz GSM Wireless Communication Signals on DMBA-Induced Mammary Tumors in Rats. *Radiat Res*. 165(2):174-180, 2006.

The purpose of the study was to investigate whether exposure to 900 MHz GSM wireless communication signals enhances mammary tumor development and growth induced by low-dose DMBA. Five hundred female Sprague-Dawley rats were treated with a single dose of 35 mg/kg DMBA and then divided into five groups in a blinded fashion: one cage control group and four exposure groups, including three microwave exposure groups and one sham exposure with specific absorption rates (SARs) of 4.0, 1.33, 0.44 and 0 W/kg, respectively. Exposure started on the day after DMBA administration and lasted 4 h/day, 5 days/week for 26 weeks. Rats were weighed and palpated weekly for the presence of tumors and were killed humanely at the end of the 26-week exposure period. All mammary glands were examined histologically. There were no statistically significant differences in body weight between sham- and GSM microwave-

exposed groups. No significant differences in overall mammary tumor incidence, latency to tumor onset, tumor multiplicity, or tumor size were observed between microwave- and sham-exposed groups. There was a tendency for reduction of mammary adenocarcinoma incidence in the lowest microwave exposure group (0.44 W/kg) compared with the sham-exposed group ($P = 0.058$). Additionally, a higher incidence of adenocarcinoma was noticed in the 4.0 W/kg group from the 15th to 26th weeks, especially in the 19th week ($P = 0.358$ compared to sham). However, neither tendency was statistically significant; thus this study does not provide evidence that GSM microwave exposure promotes mammary tumor development in rats. In the present study there were significant differences between the cage controls and the experimental groups (sham and exposure). Body weight and mammary tumor (malignant plus benign) incidence in the cage control group were significantly higher than in the sham- and GSM microwave-exposed groups. The latency to the mammary tumor onset was significantly shorter in the cage control group than in the other groups.

Yuasa K, Arai N, Okabe S, Tarusawa Y, Nojima T, Hanajima R, Terao Y, Ugawa Y. Effects of thirty minutes mobile phone use on the human sensory cortex. *Clin Neurophysiol.* 2006 Jan 22; [Epub ahead of print]

OBJECTIVE: To investigate whether the pulsed high-frequency electromagnetic field (pulsed EMF) emitted by a mobile phone for 30min has short-term effects on human somatosensory evoked potentials (SEPs). **METHODS:** We studied somatosensory evoked potentials (SEPs) in 12 normal volunteers before and after exposure to the electromagnetic field emitted by a mobile phone for 30min compared with sham exposure. In 7 out of the subjects we also measured the recovery function of the SEP. **RESULTS:** Neither SEPs nor their recovery function was affected by exposure to pulsed EMF emitted by a mobile phone or sham phone use. **CONCLUSIONS:** As far as the present methods are concerned, 30min mobile phone use has no short-term effects on the human sensory cortex. **SIGNIFICANCE:** This is the first study of SEPs after electromagnetic exposure by the mobile phone. Our results support the safety of the mobile phone.

Yurekli AI, Ozkan M, Kalkan T, Saybasili H, Tuncel H, Atukeren P, Gumustas K, Seker S. GSM Base Station Electromagnetic Radiation and Oxidative Stress in Rats. *Electromagn Biol Med.* 2006;25(3):177-188, 2006.

The ever increasing use of cellular phones and the increasing number of associated base stations are becoming a widespread source of nonionizing electromagnetic radiation. Some biological effects are likely to occur even at low-level EM fields. In this study, a gigahertz transverse electromagnetic (GTEM) cell was used as an exposure environment for plane wave conditions of far-field free space EM field propagation at the GSM base transceiver station (BTS) frequency of 945 MHz, and effects on oxidative stress in rats were investigated. When EM fields at a power density of 3.67 W/m² (specific absorption rate = 11.3 mW/kg), which is well below current exposure limits, were applied, MDA (malondialdehyde) level was found to increase and GSH (reduced glutathione) concentration was found to decrease significantly ($p < 0.0001$). Additionally, there was a less significant ($p = 0.0190$) increase in SOD (superoxide dismutase).

Zareen N, Khan MY, Minhas LA. Derangement of chick embryo retinal differentiation caused by radiofrequency electromagnetic fields. *Congenit Anom (Kyoto).* 49(1):15-19, 2009.

The possible adverse effects of radiofrequency electromagnetic fields (EMF) emitted from mobile phones present a major public concern. Biological electrical activities of the human body are vulnerable to interference from oscillatory aspects of EMF, which affect fundamental cellular activities, in particular, the highly active development process of embryos. Some studies highlight the possible health hazards of EMF, while others contest the hypothesis of biological impact of EMF. The present study was designed to observe the histomorphological effects of EMF emitted by a mobile phone on the retinae of developing chicken embryos. Fertilized chicken eggs were exposed to a ringing mobile set on silent tone placed in the incubator at different ages of development. After exposure for the scheduled duration the retinae of the embryos were dissected out and processed for histological examination. The control and experimental embryos were statistically compared for retinal thickness and epithelial pigmentation grades. Contrasting effects of EMF on the retinal histomorphology were noticed, depending on the duration of exposure. The embryos exposed for 10 post-incubation days exhibited decreased retinal growth and mild pigmentation of the epithelium. Growth retardation reallocated to growth enhancement on increasing EMF exposure for 15 post-incubation days, with a shift of pigmentation grade from mild to intense. We conclude that EMF emitted by a mobile phone cause derangement of chicken embryo retinal differentiation.

Zeng QL, Weng Y, Chen GD, Lu DQ, Chiang H, Xu ZP [Effects of GSM 1800 MHz radiofrequency electromagnetic fields on protein expression profile of human breast cancer cell MCF-7.] **Zhonghua Yu Fang Yi Xue Za Zhi.** 40(3):153-158, 2006.

[Article in Chinese]

OBJECTIVE: To study the effects of GSM 1800 MHz radiofrequency electromagnetic fields (RF EMF) exposure on protein expression profile of human breast cancer cell line (MCF-7), as to exploring the possible effects on normal cell physiological function. **METHODS:** MCF-7 cells were continuously or intermittently (5 minutes field on followed by 10 minutes off) exposed to RF EMF for different duration (1 hour, 3 hours, 6 hours, 12 hours, or 24 hours) at an average specific absorption rate (SAR) of 3.5 W/kg. The extracted proteins were separated by 2-dimensional electrophoresis and the protein-spot distribution of the silver-stained gels was analyzed by using PDQuest software 7.1. Each experiment was repeated three times. **RESULTS:** On the average, around 1100 proteins were detected using pH 4 - 7 IPG strip. There were no differential proteins found under continuous exposure at SAR of 3.5 W/kg for 6 hours. Under other exposure conditions, we found various differentially expressed proteins in exposure groups as compared with the sham-exposed controls. Especially in 3 hours intermittent exposure and 12 hours continuous exposure, eighteen and seven differential proteins were detected, respectively. The categories and functions of these differentially expressed proteins were analyzed by searching of SWISS-PROT protein database, which suggested that these proteins should be related to the functions of biosynthesis, signal transduction, and DNA damage and repair. **CONCLUSIONS:** Data indicated that the protein expression changes induced by RF radiation might depend on exposure duration and mode. Many biological processes might be affected by RF exposure.

Zeng Q, Chen G, Weng Y, Wang L, Chiang H, Lu D, Xu Z. Effects of Global System for Mobile Communications 1800 MHz radiofrequency electromagnetic fields on gene and protein expression in MCF-7 cells. **Proteomics.** 2006 Aug 3; [Epub ahead of print]

Despite many studies over a decade, it still remains ambiguous as to the real biological effects induced by radiofrequency electromagnetic fields (RF EMF) utilized in mobile telephony. Here we investigated global gene and protein responses to RF EMF simulating the Global System for Mobile Communications (GSM) 1800 MHz signal in human breast cancer cell line MCF-7 using genomic and proteomic approaches. GeneChip analysis identified a handful of consistent changed genes after exposure to RF EMF at specific absorption rates (SAR) of up to 3.5 W/kg for 24 h. However, these differentially transcribed genes could not be further confirmed by real-time RT-PCR assay. Meanwhile, systematic proteome analysis of the MCF-7 cells revealed that a few but different proteins were differentially expressed under continuous or intermittent RF EMF exposure at SAR of 3.5 W/kg for 24 h or less, implying that the observed effects might have occurred by chance. Overall, the present study does not provide convincing evidence that RF EMF exposure under current experimental conditions can produce distinct effects on gene and protein expression in the MCF-7 cells.

Zeni, O., Schiavoni, A. S., Sannino, A., Antolini, A., Forigo, D., Bersani, F. and Scarfi, M. R. Lack of Genotoxic Effects (Micronucleus Induction) in Human Lymphocytes Exposed In Vitro to 900 MHz Electromagnetic Fields. **Radiat. Res.** 160, 152-158, 2003.

In the present study, we investigated the induction of genotoxic effects in human peripheral blood lymphocytes after exposure to electromagnetic fields used in mobile communication systems (frequency 900 MHz). For this purpose, the incidence of micronuclei was evaluated by applying the cytokinesis-block micronucleus assay. Cytotoxicity was also investigated using the cytokinesis-block proliferation index. The experiments were performed on peripheral blood from 20 healthy donors, and several conditions were tested by varying the duration of exposure, the specific absorption rate (SAR), and the signal [continuous-wave (CW) or GSM (Global System of Mobile Communication) modulated signal]. The following exposures were carried out: (1) CW intermittent exposure (SAR = 1.6 W/kg) for 6 min followed by a 3-h pause (14 on/off cycles); (2) GSM signal, intermittent exposure as described in (1); (3) GSM signal, intermittent exposure as described in (1) 24 h before stimulation with phytohemagglutinin (8 on/off cycles); (4) GSM signal, intermittent

exposure (SAR = 0.2 W/kg) 1 h per day for 3 days. The SARs were estimated numerically. No statistically significant differences were detected in any case in terms of either micronucleus frequency or cell cycle kinetics.

Zeni O, Romano M, Perrotta A, Lioi MB, Barbieri R, d'Ambrosio G, Massa R, Scarfi MR. Evaluation of genotoxic effects in human peripheral blood leukocytes following an acute in vitro exposure to 900 MHz radiofrequency fields. *Bioelectromagnetics*. 26(4):258-265, 2005.

Human peripheral blood leukocytes from healthy volunteers have been employed to investigate the induction of genotoxic effects following 2 h exposure to 900 MHz radiofrequency radiation. The GSM signal has been studied at specific absorption rates (SAR) of 0.3 and 1 W/kg. The exposures were carried out in a waveguide system under strictly controlled conditions of both dosimetry and temperature. The same temperature conditions (37.0 ± 0.1 degrees C) were realized in a second waveguide, employed to perform sham exposures. The induction of DNA damage was evaluated in leukocytes by applying the alkaline single cell gel electrophoresis (SCGE)/comet assay, while structural chromosome aberrations and sister chromatid exchanges were evaluated in lymphocytes stimulated with phytohemagglutinin. Alterations in kinetics of cell proliferation were determined by calculating the mitotic index. Positive controls were also provided by using methyl methanesulfonate (MMS) for comet assay and mitomycin-C (MMC), for chromosome aberration, or sister chromatid exchange tests. No statistically significant differences were detected in exposed samples in comparison with sham exposed ones for all the parameters investigated. On the contrary, the positive controls gave a statistically significant increase in DNA damage in all cases, as expected. Thus the results obtained in our experimental conditions do not support the hypothesis that 900 MHz radiofrequency field exposure induces DNA damage in human peripheral blood leukocytes in this range of SAR.

Zeni, O., Di Pietro, R., d'Ambrosio, G., Massa, R., Capri, M., Naarala, J., Juutilainen, J. and Scarfi, M. R. Formation of Reactive Oxygen Species in L929 Cells after Exposure to 900 MHz RF Radiation with and without Co-exposure to 3-Chloro-4-(dichloromethyl)-5-hydroxy-2(5H)-furanone. *Radiat. Res.* 167, 306-311, 2007.

The aim of this study was to investigate the induction of reactive oxygen species in murine L929 fibrosarcoma cells exposed to radiofrequency (RF) radiation at 900 MHz, with or without co-exposure to 3-chloro-4-(dichloromethyl)-5-hydroxy-2(5H)-furanone (MX), a potent environmental carcinogen produced during chlorination of drinking water. Both continuous-wave and GSM mobile phone signals were applied for 10 or 30 min at specific absorption rates of 0.3 and 1 W/kg. Simultaneous sham exposures were performed for each exposure condition. MX treatment was performed at a subtoxic level of 500 μ M, and the RF-field exposure was carried out during the first 10 or 30 min of the chemical treatment. The formation of reactive oxygen species was followed soon after the exposure and at different harvesting times until 1 h after RF-field treatment. The study provided no indication that 900 MHz RF-field exposure, either alone or in combination with MX, induced formation of reactive oxygen species under any of the experimental conditions investigated. In contrast, exposure to MX resulted in a statistically significant increase in the formation of reactive oxygen species for all the treatment durations investigated, confirming that MX is an inductor of oxidative stress in L929 cells.

Zeni O, Schiavoni A, Perrotta A, Forigo D, Deplano M, Scarfi MR. Evaluation of genotoxic effects in human leukocytes after in vitro exposure to 1950 MHz UMTS radiofrequency field. *Bioelectromagnetics*. 2007 Nov 20; [Epub ahead of print]

In the present study the third generation wireless technology of the Universal Mobile Telecommunication System (UMTS) signal was investigated for the induction of genotoxic effects in human leukocytes. Peripheral blood from six healthy donors was used and, for each donor, intermittent exposures (6 min RF on, 2 h RF off) at the frequency of 1950 MHz were conducted at a specific absorption rate of 2.2 W/kg. The exposures were performed in a transverse electro magnetic (TEM) cell hosted in an incubator under strictly controlled conditions of temperature and dosimetry. Following long duration intermittent RF exposures (from 24 to 68 h) in different stages of the cell cycle, micronucleus formation was evaluated by applying the cytokinesis block micronucleus assay, which also provides information on cell division kinetics. Primary DNA damage (strand breaks/alkali labile sites) was also investigated following 24 h of intermittent RF exposures, by applying the alkaline single cell gel electrophoresis (SCG)/comet assay. Positive controls were included by treating cell cultures with Mitomycin-C and methylmethanesulfonate for micronucleus and comet assays, respectively. The results obtained indicate that intermittent exposures of human lymphocytes in different stages of cell cycle do not induce either an increase in micronucleated cells, or change in cell cycle kinetics; moreover, 24 h intermittent exposures also fail to

affect DNA structure of human leukocytes soon after the exposures, likely indicating that repairable DNA damage was not induced.

Zhang DY, Xu ZP, Chiang H, Lu DQ, Zeng QL. [Effects of GSM 1800 MHz radiofrequency electromagnetic fields on DNA damage in Chinese hamster lung cells.] *Zhonghua Yu Fang Yi Xue Za Zhi*. 40(3):149-152, 2006.
[Article in Chinese]

OBJECTIVE: To study the effects of GSM 1800 MHz radiofrequency electromagnetic fields (RF EMF) on DNA damage in Chinese hamster lung (CHL) cells. **METHODS:** The cells were intermittently exposed or sham-exposed to GSM 1800 MHz RF EMF (5 minutes on/10 minutes off) at a special absorption rate (SAR) of 3.0 W/kg for 1 hour or 24 hours. Meanwhile, cells exposed to 2-acetaminofluorene, a DNA damage agent, at a final concentration of 20 mg/L for 2 hours were used as positive control. After exposure, cells were fixed by using 4% paraformaldehyde and processed for phosphorylated form of H2AX (gammaH2AX) immunofluorescence measurement. The primary antibody used for immunofluorescence was mouse monoclonal antibody against gammaH2AX and the secondary antibody was fluorescein isothiocyanate (FITC)-conjugated goat anti-mouse IgG. Nuclei were counterstained with 4, 6-diamidino-2-phenylindole (DAPI). The gammaH2AX foci and nuclei were visualized with an Olympus AX70 fluorescent microscope. Image Pro-Plus software was used to count the gammaH2AX foci in each cell. For each exposure condition, at least 50 cells were selected to detect gammaH2AX foci. Cells were classified as positive when more than five foci were detected. The percentage of gammaH2AX foci positive cells was adopted as the index of DNA damage. **RESULTS:** The percentage of gammaH2AX foci positive cell of 1800 MHz RF EMF exposure for 24 hours (37.9 +/- 8.6)% or 2-acetylaminofluorene exposure (50.9 +/- 9.4)% was significantly higher compared with the sham-exposure (28.0 +/- 8.4)%. However, there was no significant difference between the sham-exposure and RF EMF exposure for 1 hour (31.8 +/- 8.7)%. **CONCLUSION:** 1800 MHz RF EMF (SAR, 3.0 W/kg) for 24 hours might induce DNA damage in CHL cells.

Zhao R, Zhang SZ, Yao GD, Lu DQ, Jiang H, Xu ZP.[Effect of 1.8 GHz radiofrequency electromagnetic fields on the expression of microtubule associated protein 2 in rat neurons] *Zhonghua Lao Dong Wei Sheng Zhi Ye Bing Za Zhi*. 24(4):222-225, 2006.

[Article in Chinese]

OBJECTIVE: To investigate the changes of gene expression in rat neurons induced by 1.8 GHz radiofrequency electromagnetic fields (RF EMF) and to screen for the RF EMF-responsive genes. **METHODS:** Newly-born SD rats in 24 hours were sacrificed to obtain cortex and hippocampus neurons. The cells were divided randomly into two groups: the experiment group (the irradiation group) and the control group (the false irradiation group). In the irradiation group, after twelve days' culture, neurons were exposed to 1.8 GHz RF EMF modulated by 217 Hz at a specific absorption rate (SAR) of 2 W/kg for 24 hours (5 minutes on/10 minutes off) while in the false control group, the neurons were put in the same waveguide as in the irradiation group, but were not exposed to any irradiation. The total RNA was isolated and purified immediately after exposure. The affymetrix rat neurobiology U34 assay was used for detecting the changes in gene expression profile according to the manufacturer's instruction. RF EMF-responsive candidate gene was confirmed by using ribonuclease protection assay (RPA). **RESULTS:** Among 1200 candidate genes, the expression levels of 34 genes were up or down regulated. Microtubule associated protein 2 (Map2) gene was selected as the candidate and subjected to further analysis. RPA data clearly revealed that Map2 was statistically significantly up-regulated after neurons were exposed to the RF EMF ($P < 0.05$). **CONCLUSION:** The modulation of gene expression and function of Map2 as a neuron specific cytoskeleton protein is crucial to maintain the normal framework and function of neurons. The finding that 1.8 GHz RF EMF exposure increases the expression of Map2 might indicate some unknown effects of RF EMF on neurons.

Zhao R, Zhang S, Xu Z, Ju L, Lu D, Yao G. Studying gene expression profile of rat neuron exposed to 1800MHz radiofrequency electromagnetic fields with cDNA microassay. *Toxicology*. 235(3):167-175, 2007.

A widespread use of mobile phone (MP) evokes a growing concern for their possible adverse effects on human, especially the brain. Gene expression is a unique way of characterizing how cells and organism adapt to changes in the external environment, so the aim of this investigation was to determine whether 1800 MHz radiofrequency electromagnetic fields

(RF EMF) can influence the gene expression of neuron. Affymetrix Rat Neurobiology U34 array was applied to investigate the changes of gene expression in rat neuron after exposed to the pulsed RF EMF at a frequency of 1800 MHz modulated by 217 Hz which is commonly used in MP. Among 1200 candidate genes, 24 up-regulated genes and 10 down-regulated genes were identified after 24-h intermittent exposure at an average special absorption rate (SAR) of 2 W/kg, which are associated with multiple cellular functions (cytoskeleton, signal transduction pathway, metabolism, etc.) after functional classification. The results were further confirmed by quantitative real-time polymerase chain reaction (RT PCR). The present results indicated that the gene expression of rat neuron could be altered by exposure to RF EMF under our experimental conditions.

Zhao TY, Zou SP, Knapp PE Exposure to cell phone radiation up-regulates apoptosis genes in primary cultures of neurons and astrocytes. Neurosci Lett. 2006 Dec 20; [Epub ahead of print].

The health effects of cell phone radiation exposure are a growing public concern. This study investigated whether expression of genes related to cell death pathways are dysregulated in primary cultured neurons and astrocytes by exposure to a working Global System for Mobile Communication (GSM) cell phone rated at a frequency of 1900MHz. Primary cultures were exposed to cell phone emissions for 2h. We used array analysis and real-time RT-PCR to show up-regulation of caspase-2, caspase-6 and Asc (apoptosis associated speck-like protein containing a card) gene expression in neurons and astrocytes. Up-regulation occurred in both "on" and "stand-by" modes in neurons, but only in "on" mode in astrocytes. Additionally, astrocytes showed up-regulation of the Bax gene. The effects are specific since up-regulation was not seen for other genes associated with apoptosis, such as caspase-9 in either neurons or astrocytes, or Bax in neurons. The results show that even relatively short-term exposure to cell phone radiofrequency emissions can up-regulate elements of apoptotic pathways in cells derived from the brain, and that neurons appear to be more sensitive to this effect than astrocytes.

Zhou ZD, Zeng QL, Zheng Y, Zhang JB, Chen HY, Lu DQ, Shao CS, Xia DJ. [Surface markers and functions of human dendritic cells exposed to mobile phone 1800 MHz electromagnetic fields.] Zhejiang Da Xue Xue Bao Yi Xue Ban. 37(1):29-33, 2008.

[Article in Chinese]

OBJECTIVE: To investigate the effects of mobile phone 1800 MHz electromagnetic fields (EMF) on the surface markers and the functions of human dendritic cells (DC). **METHODS:** Human DCs were exposed to intermittent 5 min on/10 min off EMF with specific absorption rates (SAR) 4 W/kg for 0 h, 1 h, 12 h or 24 h, respectively. FACS analysis was used to detect the positive percentage of DC surface markers including HLA-DR and co-stimulatory molecules such as CD80, CD86, CD40 and CD11c. CCK-8 kit was adopted to examine the function of allo-mixed lymphocyte reaction (allo-MLR) of DC, and enzyme linked immunosorbent assay (ELISA) to identify the levels of IL-12p70 and TNF-alpha secreted by DC. **RESULT:** Compared with the sham radiation group, after exposure to the electromagnetic fields for 1 h, 12 h, or 24 h, HLA-DR, CD80, CD86 and CD40 were all declined except CD11c. The ability of DC allo-MLR in each exposure group was decreased significantly ($P < 0.05$), especially in the 24 h exposure group. However, the secreted levels of IL-12p70 and TNF-alpha of DC in each exposure group remained no changed. **Conclusion:** The study showed that EMF exposure could down-regulate the surface molecules and stimulation ability of human DC.

Zmyslony M, Politanski P, Rajkowska E, Szymczak W, Jajte J. Acute exposure to 930 MHz CW electromagnetic radiation in vitro affects reactive oxygen species level in rat lymphocytes treated by iron ions. *Bioelectromagnetics*. 25(5):324-328, 2004.

The aim of this study was to test the hypothesis that the 930 MHz continuous wave (CW) electromagnetic field, which is the carrier of signals emitted by cellular phones, affects the reactive oxygen species (ROS) level in living cells. Rat lymphocytes were used in the experiments. A portion of the lymphocytes was treated with iron ions to induce oxidative

processes. Exposures to electromagnetic radiation (power density 5 W/m², theoretical calculated SAR = 1.5 W/kg) were performed within a GTEM cell. Intracellular ROS were measured by the fluorescent probe dichlorofluorescein diacetate (DCF-DA). The results show that acute (5 and 15 min) exposure does not affect the number of produced ROS. If, however, FeCl₂ with final concentration 10 microg/ml was added to the lymphocyte suspensions to stimulate ROS production, after both durations of exposure, the magnitude of fluorescence (ROS level during the experiment) was significantly greater in the exposed lymphocytes. The character of the changes in the number of free radicals observed in our experiments was qualitatively compatible with the theoretical prediction from the model of electromagnetic radiation effect on radical pairs.

Zook BC, Simmens SJ, The Effects of 860 MHz Radiofrequency Radiation on the Induction or Promotion of Brain Tumors and Other Neoplasms in Rats. *Radiat Res* 155(4):572-583, 2001.

Zook, B. C. and Simmens, S. J. The Effects of 860 MHz Radiofrequency Radiation on the Induction or Promotion of Brain Tumors and Other Neoplasms in Rats. Sprague-Dawley rats were irradiated with a continuous-wave (CW) or a pulsed-wave (P) radiofrequency (RF) for 6 h/day, 5 days/week from 2 up to 24 months of age. The RFs emanated from dipole antennas (1 W average output) 2.0 +/- 0.5 cm from the tip of each rat's nose. The RFs had an 860 MHz frequency, and the specific absorption rate was 1.0 W/kg averaged over the brain. Fifteen groups of 60 rats (900 total) were formed from offspring of females injected i.v. with 0 (groups 1, 2, 9, 10, 13), 2.5 (groups 5, 6, 7, 8, 11, 12, 14) or 10 mg/kg (groups 3, 4, 15) ethylnitrosourea (ENU) to induce brain tumors. Groups 1, 3, 5 and 7 received the PRF, and groups 9 and 11 the CWRF; groups 2, 4, 6, 8, 10 and 12 were sham-irradiated, and groups 13-15 were cage controls. All rats but 2, totaling 898, were necropsied, and major tissues were studied histopathologically. There was no statistically significant evidence that the PRF or CWRF induced neoplasia in any tissues. Additionally, there was no significant evidence of promotion of cranial or spinal nerve or spinal cord tumors. The PRF or CWRF had no statistically significant effect on the number, volume, location, multiplicity, histological type, malignancy or fatality of brain tumors. There was a trend for the group that received a high dose of ENU and was exposed to the PRF to develop fatal brain tumors at a higher rate than its sham group; however, the result was not significant using the log-rank test (P = 0.14, 2-tailed). No statistically significant differences were related to the PRF or CWRF compared to controls in the low- or zero-dose groups regarding tumors of any kind.

Zook BC, Simmens SJ. The Effects of Pulsed 860 MHz Radiofrequency Radiation on the Promotion of Neurogenic Tumors in Rats. *Radiat. Res.* 165, 608-615, 2006.

In a previous study, this laboratory reported a statistically nonsignificant trend for shortened latency of ethylnitrosourea (ENU)-induced brain tumors in Sprague-Dawley rats exposed to an 860 MHz pulsed radiofrequency (RF) signal. The present study was designed to investigate further any promoting effect of the pulsed RF signal on latency and other characteristics of neurogenic tumors in the progeny of pregnant rats treated with 6.25 or 10 mg/kg ENU. The resulting 1080 offspring were randomized equally by number, sex and ENU dose into pulsed RF, sham and cage control groups. The rats were exposed to the pulsed RF signal 6 h per day 5 days per week; the sham-exposed group was similarly confined for the same periods, and the cage controls were housed in standard cages. An essentially equal number of rats from each group were killed humanely every 30 days between the ages of 171 and 325 days; 32 rats died and 225 rats were killed when they were moribund. Postmortem examinations on the 1080 rats revealed 38 spinal cord tumors, 191 spinal nerve tumors, 232 cranial nerve tumors, and 823 brain tumors. A methodical study of the tumor characteristics disclosed no evidence that exposure to the pulsed RF signal affected the incidence, malignancy, volume, multiplicity, latency or fatality associated with any kind of neurogenic tumor.

Zotti-Martelli L, Peccatori M, Maggini V, Ballardini M, Barale R.

Individual responsiveness to induction of micronuclei in human lymphocytes after exposure in vitro to 1800-MHz microwave radiation. *Mutat Res.* 582(1-2):42-52, 2005.

The widespread application of microwaves is of great concern in view of possible consequences for human health. Many in vitro studies have been carried out to detect possible effects on DNA and chromatin structure following exposure to microwave radiation. The aim of this study is to assess the capability of microwaves, at different power densities and exposure times, to induce genotoxic effects as evaluated by the in vitro micronucleus (MN) assay on peripheral blood lymphocytes from nine different healthy donors, and to investigate also the possible inter-individual response variability. Whole blood samples were exposed for 60, 120 and 180min to continuous microwave radiation with a frequency of 1800MHz and power densities of 5, 10 and 20mW/cm². Reproducibility was tested by repeating the experiment 3 months later. Multivariate analysis showed that lymphocyte proliferation indices were significantly different among donors ($p<0.004$) and between experiments ($p<0.01$), whereas the applied power density and the exposure time did not have any effect on them. Both spontaneous and induced MN frequencies varied in a highly significant way among donors ($p<0.009$) and between experiments ($p<0.002$), and a statistically significant increase of MN, although rather low, was observed dependent on exposure time ($p=0.0004$) and applied power density ($p=0.0166$). A considerable decrease in spontaneous and induced MN frequencies was measured in the second experiment. The results show that microwaves are able to induce MN in short-time exposures to medium power density fields. Our data analysis highlights a wide inter-individual variability in the response, which was confirmed to be a characteristic reproducible trait by means of the second experiment.

Dosimetry studies

Anderson V, Joyner KH, Specific absorption rate levels measured in a phantom head exposed to radio frequency transmissions from analog hand-held mobile phones. *Bioelectromagnetics* 16(1):60-69, 1995.

Electric fields (E-fields) induced within a phantom head from exposure to three different advanced mobile phone system (AMPS) hand-held telephones were measured using an implantable E-field probe. Measurements were taken in the eye nearest the phone and along a lateral scan through the brain from its centre to the side nearest the phone. During measurement, the phones were positioned alongside the phantom head as in typical use and were configured to transmit at maximum power (600 mW nominal). The specific absorption rate (SAR) was calculated from the in situ E-field measurements, which varied significantly between phone models and antenna configuration. The SARs induced in the eye ranged from 0.007 to 0.21 W/kg. Metal-framed spectacles enhanced SAR levels in the eye by 9-29%. In the brain, maximum levels were recorded at the measurement point closest to the phone and ranged from 0.12 to 0.83 W/kg. These SARs are below peak spatial limits recommended in the U.S. and Australian national standards [IEEE Standards Coordinating Committee 28 (1991): C95.1-1991 and Standards Australia (1990): AS2772.1-1990] and the IRPA guidelines for safe exposure to radio frequency (RF) electromagnetic fields [IRPA (1988): Health Phys 54:115-123]. Furthermore, a detailed thermal analysis of the eye indicated only a 0.022 degrees C maximum steady-state temperature rise in the eye from a uniform SAR loading of 0.21 W/kg. A more approximate thermal analysis in the brain also indicated only a small maximum temperature rise of 0.034 degrees C for a local SAR loading of 0.83 W/kg.

Dimbylow PJ, Mann SM. SAR calculations in an anatomically realistic model of the head for mobile communication transceivers at 900 MHz and 1.8 GHz. *Phys. Med. Biol.* 39:1537-1553, 1994.

Abstract. A new mathematical model of the head has been constructed from a set of serial MRI slices from one subject. Finite-difference time-domain (FDTD) calculations of the specific energy absorption rate (SAR) have been performed on this model with a 2 mm resolution for a generic mobile communication transceiver represented by a quarter-wavelength monopole on a metal box. The antenna was mounted either at the centre or corner of the top face of the box. The frequencies considered were 900 MHz and 1.8 GHz. Three irradiation geometries were considered, a vertical handset in front of the eye and vertical and horizontal orientations at the side of the ear. The effect of a hand grasping the handset was considered. The head model was scaled to represent the head of an infant and a subset of calculations was performed to verify that the SAR deposited in the infant head did not exceed that in the adult. Results are also presented for a half-wavelength dipole. The maximum SAR values produced by the generic transceiver for the horizontal orientation at the side of the head which is the most typical position, averaged over 10 g of tissue at 900 MHz and 1.8 GHz, are 2.1 and 3.0 W kg⁻¹ per W of radiated power. The corresponding values over 1 g of tissue are 2.3 and 4.8 W kg⁻¹ per W at 900 MHz and 1.8 GHz. However, if one were to consider all possible operational conditions, the placement of the transceiver in

front of the eye will give 3.1 and 4.6 W kg⁻¹ per W averaged over 10 g of tissue and 4.7 and 7.7 W kg⁻¹ per W over 1 g of tissue at 900 MHz and 1.8 GHz, respectively.

Gandhi OP, Lazzi G, Tinniswood A, Yu QS, Comparison of numerical and experimental methods for determination of SAR and radiation patterns of handheld wireless telephones. *Bioelectromagnetics Suppl* 4:93-101, 1999.

Some recent developments in both the numerical and experimental methods for determination of SARs and radiation patterns of handheld wireless telephones are described, with emphasis on comparison of results using the two methods. For numerical calculations, it was possible to use the Pro-Engineer CAD Files of cellular telephones for a realistic description of the device. Also, we used the expanding grid formulation of the finite-difference time-domain (FDTD) method for finer-resolution representation of the coupled region, including the antenna, and an increasingly coarser representation of the more-distant, less-coupled region. Together with the truncation of the model of the head, this procedure led to a saving of computer memory needed for SAR calculations by a factor of over 20. Automated SAR and radiation pattern measurement systems were used to validate both the calculated 1-g SARs and radiation patterns for several telephones, including some research test samples, using a variety of antennas. Even though widely different peak 1-g SARs were obtained, ranging from 0.13 to 5.41 W/kg, agreement between the calculated and the measured data for these telephones, five each at 835 and 1900 MHz, was excellent and generally within +/-20% (+/-1 dB). An important observation was that for a maximum radiated power of 600 mW at 800/900 MHz, which may be used for telephones using AMPS technology, the peak 1-g SARs can be higher than 1.6 W/kg unless antennas are carefully designed and placed further away from the head.

Van de Kamer JB, Lagendijk, JJW, Computation of high-resolution SAR distributions in a head due to a radiating dipole antenna representing a hand-held mobile phone. *Phys. Med. Biol.* 47:1827-1835, 2002.

SAR distributions in a healthy female adult head as a result of a radiating vertical dipole antenna (frequency 915 MHz) representing a hand-held mobile phone have been computed for three different resolutions: 2 mm, 1 mm and 0.4 mm. The extremely high resolution of 0.4 mm was obtained with our quasistatic zooming technique, which is briefly described in this paper. For an effectively transmitted power of 0.25 W, the maximum averaged SAR values in both cubic- and arbitrary-shaped volumes are, respectively, about 1.72 and 2.55 W kg⁻¹ for 1 g and 0.98 and 1.73 W kg⁻¹ for 10 g of tissue. These numbers do not vary much (<8%) for the different resolutions, indicating that SAR computations at a resolution of 2 mm are sufficiently accurate to describe the large-scale distribution. However, considering the detailed SAR pattern in the head, large differences may occur if high-resolution computations are performed rather than low-resolution ones. These deviations are caused by both increased modelling accuracy and improved anatomical description in higher resolution simulations. For example, the SAR profile across a boundary between tissues with high dielectric contrast is much more accurately described at higher resolutions. Furthermore, low-resolution dielectric geometries may suffer from loss of anatomical detail, which greatly affects small-scale SAR distributions. Thus, for strongly inhomogeneous regions high-resolution SAR modelling is an absolute necessity.